Kenwood TS-590S

Peter Hart reviews the latest HF & 50MHz transceiver

PHOTO 1: General view of the Kenwood TS-590S.

INTRODUCTION. Kenwood has been one of the key forces in the design and supply of amateur transceivers ever since these first became mass-produced items. Many classic models have been produced by them over the years and the excellence of these designs is borne out by the number that are still in use by their loyal and contented owners. More recently the number of new models has reduced; indeed, it is now seven years since the last Kenwood HF transceiver so the announcement of a new model, the TS-590S, has (not surprisingly) been greeted with a great amount of interest. Shortly after receiving the review radio I produced a short summary of my first impressions for the December *RadCom* and the full review now follows.

BASIC FUNCTIONS. The TS-590S is a mid-sized radio measuring 270(w) x 96(h) x 291mm (d) and weighs about 7.4kg. This is sufficiently small to be easily transportable but of adequate size to be comfortable to operate. The radio requires a 13.8V supply.

It contains a single receiver tuning 30kHz to 60MHz, although the performance is not specified over the full range. The transmitter is enabled on the amateur bands and delivers nominally 100W output power. Transmit operation on 5MHz is standard in US models but can be enabled by Kenwood dealers in the UK. This gives continuous transmit coverage across the 5MHz band for all modes but the discrete channels are best stored to memory for easy access. A low-level drive output is provided giving about 1mW transmit signal on the 136kHz band as well as transverter drive from any of the HF bands. The low level LF transmit range can be extended to 522kHz with a dealer modification, useful if 500kHz becomes a permanent allocation.

Individual buttons select the bands with a triple band stacking register where one of three last used combinations of frequency, mode and other settings is returned for each press of the band key. Individual buttons also select the usual modes, with both sidebands available on CW and FSK and wide or narrow deviations on FM. A data button selects data mode on SSB and FM, the normal way of interfacing to PC applications (via the sound card); shifts and bandwidths all settable. Modes can be selected automatically by setting up a mode-frequency map.

The front panel is well laid out, with most functions directly accessible from front panel controls in a logical way. The display uses LCD technology with selectable yellow or green LED backlighting. It is clear and bright with a good viewing angle. It also retains excellent visibility in bright lighting or direct sunlight, unlike many other display technologies. The meter displays use a bargraph format and receiver filter bandwidths are similarly shown as a graphical bar. A separate button displays filter bandwidths and shifts numerically for about 1 second. The frequency is displayed to 10Hz resolution and both frequencies are displayed for split frequency operation.

The menu system is very comprehensive with 88 items and is easy to access and set. It uses scrolling display annotation. Two entirely separate sets of parameters may be stored, as Menu A and Menu B. This can be useful for optimising different operating environments such as contesting and local rag-chewing or for field day operation where two operators have different preferences for the way the radio is set up. Access to selected menu items can be simplified by setting up a quick menu, which is a customised abbreviated menu list, or by allocating menu items to programmable function keys. There are two programmable function keys on the front panel and a further four with the MC-47 microphone (available as an optional extra). Alternatively, the up/down keys on the standard microphone supplied with the radio can be reassigned as function keys. All menu items, second level key functions and some otherwise inaccessible functions can be assigned to any of the programmable keys.

There are two antenna sockets on the rear panel and there is also a separate receive-only antenna connector. Key jacks are only fitted on the rear panel, one for connecting a paddle to the internal keyer and a separate socket for external keying. Other rear panel connectors are fairly minimal: a DIN connector for audio and interfacing lines for the data modes and a separate DIN connector for linear control. Menu items allow for both fast and slow linear switching separately for HF and 50MHz but there is only one linear control line. A dedicated connector interfaces to the AT-300 external ATU.

For connecting to a PC, a USB interface and a 9-pin D connector COM port are provided. The USB port allows for both PC control and for passing audio to and from external applications. Software and port drivers are available from the Kenwood US website [1]. As with other recent Kenwood radios, the built-in firmware is upgradeable. Again, full details are given on the Kenwood US website. The 90 page instruction manual provided with the radio is comprehensive and written in a very compact style but in some cases is not particularly clear. There are no technical descriptions, circuit diagrams or CAT details provided, but a separate CAT manual is downloadable from the Kenwood website. A further five instruction manuals in different languages are provided with the radio, which seems rather a waste of paper.

RADIO DESIGN AND ARCHITECTURE. The receiver in the TS-590S uses a rather novel architecture. Over most of the tuning range it is a triple conversion superhet, up-converting to a first IF of 73MHz, then to the second IF of 10.7MHz and finally to 24kHz to feed the DSP. A 15kHz bandwidth roofing filter is fitted at the 73MHz IF with 15kHz, 6kHz or 2.7kHz bandwidth filters at the second IF depending on mode and selected bandwidth. On certain amateur bands (160, 80, 40, 20 and 15m) and with bandwidths less than 2.7kHz a separate first mixer down-converts directly to the second IF, now at

PHOTO 2: Top view with covers removed showing PA, output filters and auto ATU.

PHOTO 3: Underneath view showing signal processing boards.

11.374MHz, bypassing the up-conversion process. Narrow roofing filters of 2.7kHz or 500Hz bandwidth are selected automatically in the down-conversion path, depending on selected bandwidth, yielding much better close-in performance compared with the up-conversion path. A 32 bit floating-point DSP is used to provide IF channel filtering, demodulation, noise reduction, audio processing and AGC functions. On FM, there is an additional conversion from the second IF to 455kHz where a separate FM IC performs demodulation and passes audio to the DSP. On this mode the DSP is used purely for audio filtering functions.

The receiver front end uses a switchable bipolar preamplifier with nominally 12dB gain up to 21.5MHz and 20dB gain above. There is a switchable attenuator for really strong signal situations and 13 input bandpass filters covering the total frequency range of the receiver. Both first mixers use a quad arrangement of MOSFETs and the local oscillator feeds are derived directly from DDS chips (AD9951) without the usual PLL. This can result in much better phase noise performance but low-level spurious outputs can be more of a problem. There is a normal crystal reference oscillator but a 0.5ppm TCXO is available as an optional extra. The transmit signal path uses the up-conversion frequency scheme in reverse.

The radio is solidly constructed in conventional style using a substantial diecast frame on which the circuit boards are mounted together with a wrap-around case. A bail stand tilts the front panel to improve visibility and operating ease. Dual internal fans cool the PA, operating only when the temperature rises. There is substantial internal heatsinking so these fans rarely operate in normal use. A 7cm speaker fits in the case top.

RECEIVER FEATURES. The radio is fitted with a 45mm diameter main tuning drive, smooth in operation and with drag adjustment. With 1000 steps per revolution and 10Hz steps on CW/SSB or 100Hz steps on AM/FM, it combines precise tuning with fast frequency navigation. Fine-tuning at one tenth of these rates is selectable, as are lower steps per revolution if desired. Rapid tuning in a variety of mode-dependant step sizes is performed by a small click-step rotary control, which is also used to select menu items, memory channels and other functions. The frequency may be entered directly using the band keys as a numeric keypad and a history list of the last 10 frequencies entered this way is stored for rapid recall.

The usual A/B twin VFOs are provided together with split frequency operation and a TFSET key for quick monitoring and tuning the transmit frequency during split frequency operation. RIT and XIT are both available to give incremental tuning over a range of ±10kHz. An auto-tune feature fine tunes the receiver to give the correct CW pitch, but this is best avoided if there are any interfering signals in the passband. There are 99 conventional memory channels and a further 10 for storing programmable scan limits. The usual memory transfer functions are provided and name tags of up to eight characters may be assigned. A separate quick access memory is included, which stores up to 10 channels. Comprehensive scanning is provided between frequency limits, across memory channels or groups.

Two different methods are used to set the IF channel bandwidth, depending on the mode, using dual concentric rotary controls. On SSB, AM and FM, slope tuning is used, with separate control of the low and high frequency cut-offs. The net bandwidth is the difference between the two. On AM and FM the quoted bandwidth is somewhat misleading. On FM it relates to the audio filtered bandwidth; the IF bandwidth is fixed at 12kHz. On AM it also relates to the audio bandwidth after demodulation but it is the IF bandwidth which is filtered to about double this value. On CW, FSK and SSB data modes these dual controls adjust bandwidth and centre frequency (shift). The default shift setting on CW is made equal to the CW pitch frequency. Bandwidths are portrayed graphically on the display but actual values are displayed for about one second at the push of a key. Bandwidth settings are stored separately for each mode. Two separate sets of bandwidths may be stored and toggled from a front panel key, the equivalent of normal/narrow settings on other radios but more versatile. There is no user access to the roofing filter selection; this is set automatically according to bandwidth and mode.

Four different notch circuits are provided. Implemented at IF is a manual notch with adjustable centre frequency and wide/narrow settings, plus a separate auto notch for automatically locating and attenuating a single interfering tone on SSB. Implemented at audio are two beat cancellation filters for SSB/AM which automatically locate and remove multiple tones. This is the function normally called auto-notch on other radios. One beat cancellation filter is more effective on continuous beats and the other on intermittent tones. Two separate DSP noise reduction functions are provided that use different algorithms and differ in their effectiveness depending on the prevailing situation. Finally in the armoury for combating interference are two noise blankers. NB1 is a conventional IF gated analogue system and NB2 performs blanking using DSP. Quite a selection to choose from!

Two AGC speeds are selectable, each with a programmable decay time constant. There are no separate audio filters for CW or data modes but a DSP audio equaliser can be enabled that has eight selectable profiles.

TRANSMIT FEATURES. The transmitter power output is variable on all modes down to about 5W and can be set separately for the HF bands

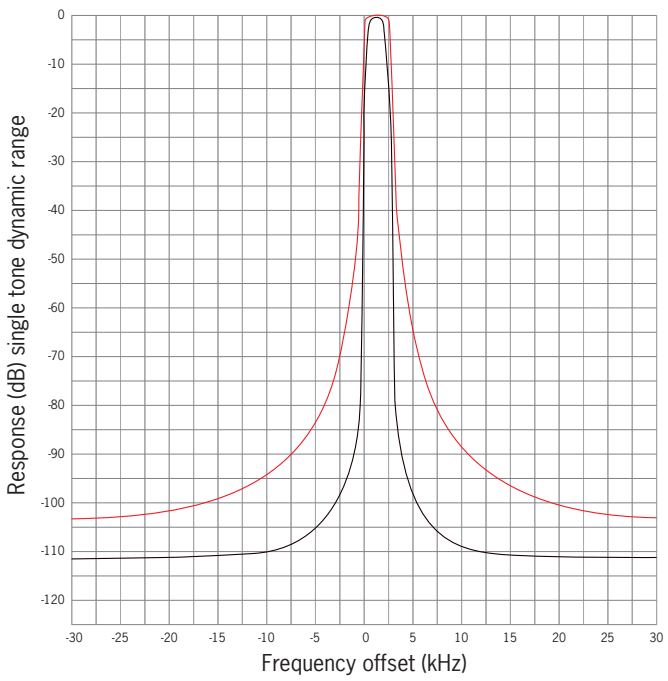

FIGURE 1: Composite selectivity curve on USB. Frequency is 1.9MHz. Black line - Rx1 bandwidth 2.3kHz, red line - Rx2 bandwidth 2.8kHz.

and 50MHz. This is useful if you use a linear on the HF bands that needs reduced drive but still require full output on 6m. Power output is indicated on the display meter, which also shows ALC, SWR or compression level. The radio includes a built-in auto ATU covering the bands 1.8 to 50MHz (including 5MHz) and will tune antennas with up to 3:1 VSWR. The ATU can be set to be in circuit on receive as well as on transmit.

On voice modes VOX, speech processor and a transmission monitor are provided and the audio bandwidth may be tailored by adjusting the low cut and high cut response. In addition, an audio equaliser may be enabled that has six selectable profiles. FM repeater operation is best achieved by setting the transmit and receive frequencies in split operation and storing to memory together with the relevant access tones. There is no direct repeater shift setting. Rx/Tx tone decoders and encoders are provided for CTCSS operation, which can use different frequencies.

On CW the rise and fall times of the keying envelope are settable from 1 to 6ms and there is the usual provision for full and semi break-in. Semi break-in drop back delay is adjustable from the front panel control. At minimum setting it is full break-in. One useful feature if you often tune around in different modes is the ability to select automatically CW mode when the key is pressed. Another useful feature is to allocate one function key for tune-up. This outputs a carrier, irrespective of mode, at a power level that can be set separately from the normal transmit power level.

An electronic keyer is built in using a paddle connected to the dedicated rear panel jack. It operates over the speed range 4 - 60wpm. The speed in wpm is indicated on the display. The weighting can be varied and made to increase or decrease with speed. Four message stores are also provided, storing 50 characters each, programmed from the paddle. The message stores are controlled from dedicated front panel keys. There is no provision to send automatically incrementing serial numbers but message stores can be cascaded seamlessly and a setting allows interruption to insert numbers or text and then resume. Messages can be set to repeat automatically after a delay.

ADDITIONAL FEATURES. The VGS-1 voice guide and message store is an optional extra. The voice guide provides voice readout in English or Japanese of the status of various radio settings depending on how it has been set up. This includes the frequency, meter readings and virtually any other settings and key presses and can be a great help for those with impaired vision. The second use of this option is to provide an audio store. This can be used to record up to two 30 second messages and a further two 15 second messages for playback on air as CQ calls or contest exchanges for example. Store 4 will also record the receiver output continuously and retain the last 30 seconds. This can be stored and played back as desired but this mode cannot be played back on air and there is an annoying delay of 20 seconds initially whilst the contents are stored to flash memory.

For use with transverters, the display can be set to indicate the transverted frequency. Three digits are available for the MHz segment, eg 144 or 432. Offsets can be stored to a resolution of 100Hz. The transmit drive source for the transverter in most cases will use the low-level 1mW drive output which disables the transmitter PA, but there is a menu option to use the PA at its lowest power level (5W). Make sure you avoid transmitting into the transverter IF output when the transverter is disabled by using the receive-only input on the TS-590S.

Kenwood has traditionally been strong in areas of communication linked with the PC and remote operation and the TS-590S is similarly supported. Kenwood provides a software control program, ARCP-590, to enable access to virtually all functions of the radio from a PC running Windows XP SP3 or later. The radio can also be controlled remotely over a network or over the internet using the Kenwood Network Command System. This uses the ARCP-590 at the operator (remote) end of the link in conjunction with the ARHP-590 host program running at the radio end of the link and with audio lines carried separately using a protocol such as VOIP. Kenwood does not supply the VOIP software, which is readily available from other sources, but the control and host software is freely downloadable from the Kenwood website [1].

Kenwood has also developed a remote control system using a radio link. Sky Command II uses a pair of the new TH-D72E VHF/UHF portables to provide full remote access to the radio, perhaps from the garden or elsewhere. The 2m and 70cm bands are used to pass receive and transmit audio and all control signals. In the USA other Kenwood VHF/UHF models are also suitably equipped.

Yet another possibility is to access the VHF/UHF packet cluster network by connecting through the COM port cable to a VHF/UHF radio and there are several Kenwood models suitably equipped. Incoming cluster spots can be passed to the TS-590S, which is then set on frequency.

I had the radio linked satisfactorily to the *Logger32* logging program using the generic Kenwood protocol for control of the radio and logging data and for passing DX Packet Cluster spots to the radio.

MEASUREMENTS. The full set of measurements is given in the table. Sensitivity measurements showed that the up-conversion receive path Rx2 was slightly more sensitive than the down-conversion path Rx1 and had about 2-3dB higher gain within the signal path. The receiver is very sensitive, particularly on 24MHz and above, where the preamplifier has an extra 8dB of gain. The sensitivity holds well at LF, achieving -123dBm at 136kHz (preamp on) and only starts to reduce at 50kHz. Sensitivity is reduced by about 16dB over the medium wave broadcast band. The S-meter calibration was moderately linear and showed about 3dB per S unit. All modes were the same, except FM which was highly compressed.

The rejection of IFs and images for the Rx1 down-conversion path was typically 75dB to 90dB. For the Rx2 up-conversion path these figures were typically better than 90dB. I searched carefully for other spurious responses as DDS circuits tend to be prone to this problem. Rx2 was very clean with no responses less than 80dB down. Rx1 was exceptionally clean with no other responses less than 100dB down except an internally generated birdie on 1827.5kHz, just above the noise level. In the most popular part of the 160m DX sector this could not be in a worse place but will probably not be a problem with full-size antennas. However, with small receive-only loops and Beverages it will be an issue. Switching to Rx2 by selecting

PHOTO 4: TS-590S rear panel.

a bandwidth greater than 2.7kHz makes this birdie disappear.

The close-in strong signal performance is limited in some cases by the AGC. A somewhat complex AGC system is used, detecting signal level in three places within the DSP signal path, one place being prior to the main channel selectivity. Hence a strong signal falling inside the roofing filters but still outside of the final channel filter will result in AGC action, reducing gain and sensitivity and result in blocking. This can be heard as a quietening of the receiver from a very strong signal just outside of the channel passband. The effect is most noticeable with the wider roofing filters and is not an issue with the 500Hz roofing filter in circuit. In other respects the AGC performance was generally clean but the attack response inserted a hole of up to 10ms in the signal. This is seen in many DSP implemented radios, although the hole was not as deep as in some radios I have measured.

The table compares the wide spaced third order intercept and dynamic range figures on different bands for Rx1 and Rx2. By measuring in 2.8kHz bandwidth all bands use Rx2. For bands that use Rx1 the measurement was also made in 2.3kHz bandwidth. The results show excellent front-end performance with Rx1 a few dB better than Rx2. Close-in measurements were made in 500Hz bandwidth with Rx1 on 7MHz and Rx2 on 10MHz. Rx1 uses the 500Hz bandwidth roofing filter and Rx2 the 2.7kHz bandwidth filter at the second IF (15kHz bandwidth filter at the first IF). The results for Rx1 are really excellent, achieving 103dB dynamic range at 2kHz spacing and 90dB at 1kHz. The results for Rx2 show the effect of the wider roofing filters. At spacings below 10kHz the dynamic range reduces by around 10dB as the signals approach the first IF filter passband. Then at 2kHz and below the signals enter the second IF filter passband: AGC takes effect (see previous paragraph), blocking occurs and meaningful measurements cannot be made.

Measurements of blocking show that the front-end can handle very strong signals. Close-in, the effects of the roofing filters can be clearly seen and signal handling reduces, although Rx1 with the 500Hz filter maintains excellent blocking performance down to 1kHz spacing (where reciprocal mixing noise starts to be seen). With the 2.7kHz roofing filter (Rx1 and Rx2), AGC comes into operation below 2kHz spacing and blocking effects

PHOTO 5: The front panel hinged down showing the PA cooling fans.

are seen at really very low levels.

The reciprocal mixing (RM) figures measured for Rx1 are excellent, similar to or better than top-end radios costing two to four times as much. The RM performance is best on the lower bands. For Rx2 the RM performance is fairly average, similar across the bands and nowhere near as good as Rx1. This is surprising considering it is the same DDS but uses a doubler to generate the higher frequencies required.

As a consequence of the excellent RM results, it was possible to measure over 80dB down the channel filter skirts in some cases (500Hz), although AGC was having an effect where the wider roofing filters were in circuit. The table shows the results down to 60dB, which are fairly typical for DSP filters. **Figure 1** shows the composite selectivity curve on USB for Rx1 and Rx2. The skirt widening with Rx2 is due to AGC close-in and reciprocal mixing further out.

On transmit, two-tone distortion products were particularly low for a 12V operated PA and the processor was very clean with negligible effect on wideband products. The audio was very clean with low distortion and most tolerant of high ALC levels and overdrive. The auto ATU reduced power by about 10 to 15%. CW rise and fall shapes were clean with negligible distortion or character shortening at 40wpm, even in full break-in mode. There was a 15ms delay on keying. AM transmit was clean with low distortion.

ON THE AIR PERFORMANCE. Over the period that I had the radio for review, I came to really like the ergonomics and appreciate the thought that Kenwood has put into implementing the various functions and features in a user-friendly way. The tuning is smooth and positive, display clear and bright and functions easy to access. The dual rotary controls are a bit small and fiddly but this is inevitable in a radio of this size. The bandwidth setting controls are a little confusing, with CW bandwidth and SSB high cut on opposite controls, but it is something you get used to.

PHOTO 6: 2nd IF roofing filters.

I used the radio briefly under contest conditions during the CQWW CW and the Ukranian DX Contests. The receiver performed very well: sensitive and lively on the quieter bands, it coped well picking out weak signals amongst strong signals and QRM on the lower bands. I could not detect any real difference in performance on-air between the up-conversion and down-conversion receivers under the conditions I experienced at the time. The audio quality using the internal speaker was excellent with good volume and no rattles. Clean performance extended down to LF, with the time-code transmissions and was also good in the AM broadcast bands. The receiver birdie on 1827.5kHz was clearly audible on my 160m receive loop and significantly stronger than the ZL8X DXpedition that was active on 1826.5kHz during the review period.

The filters performed well, with minimal ringing at low bandwidths. The various notches were all very effective. The two noise reduction modes were different in the way they transformed the signal and different from the noise reduction systems on other radios. They could be very effective in certain circumstances and quite aggressive in operation but tended to produce a digital sound with strange artefacts if overdone.

On transmit, the audio quality was reported as being excellent using the supplied microphone and the processor was clean and added extra punch. The default microphone gain setting is a bit on the high side and should be reduced. On CW the keying and the sidetone were clean and well behaved.

CONCLUSIONS. The TS-590S is an excellent all-round radio, packed with really useful features, easy to operate with well thought out and friendly ergonomics. The performance on the key five bands where it is a down-conversion radio is equal to the best radios available but at a fraction of the price. Even on the other bands it returns a very creditable performance.

With a list price around £1489, it is generally available with a significant discount and at this price it is excellent value for money.

ACKNOWLEDGEMENTS. I would like to express my gratitude to Kenwood Electronics UK for the loan of this radio.

WEBSEARCH

[1] Kenwood USA website for software downloads: www.kenwood.com/i/products/info/amateur/software_download.html

KENWOOD TS-590S MEASURED PERFORMANCE

RECEIVER MEASUREMENTS

	---SENSITIVITY SSB 10dBs+n:n---		---------INPUT FOR S9--------	
FREQUENCY	PREAMP OFF	PREAMP ON	PREAMP OFF	PREAMP ON
1.8MHz	0.35µV (-116dBm)	0.13µV (-125dBm)	50µV	16µV
3.5MHz	0.35µV (-116dBm)	0.13µV (-125dBm)	50µV	16µV
7MHz	0.35µV (-116dBm)	0.13µV (-125dBm)	56µV	16µV
10MHz	0.28µV (-118dBm)	0.14µV (-124dBm)	45µV	18µV
14MHz	0.35µV (-116dBm)	0.14µV (-124dBm)	56µV	16µV
18MHz	0.28µV (-118dBm)	0.13µV (-125dBm)	45µV	14µV
21MHz	0.4µV (-115dBm)	0.13µV (-125dBm)	56µV	11µV
24MHz	0.25µV (-119dBm)	0.1µV (-127dBm)	40µV	13µV
28MHz	0.28µV (-118dBm)	0.08µV (-129dBm)	40µV	10µV
50MHz	0.32µV (-117dBm)	0.09µV (-128dBm)	35µV	10µV

AM sensitivity (28MHz) Preamp on: 0.45µV for 10dBs+n:n at 30% mod depth
FM sensitivity (28MHz) Preamp on: 0.16µV for 12dB SINAD 3kHz pk deviation
AGC threshold Preamp on: 0.56µV
100dB above AGC threshold for <1dB audio output increase
AGC attack time: 1ms (see tet)
AGC decay time: adjustable 150ms to 5s
Max audio at 1% distortion: 1.8W into 8 ohm
Inband intermodulation products: -45 to -55dB

S-READING (7MHz)	INPUT LEVEL USB PREAMP OFF	PREAMP ON
S1	3.2µV	0.9µV
S3	5.6µV	1.8µV
S5	11µV	2.5µV
S7	20µV	6.3µV
S9	56µV	16µV
S9+20	560µV	180µV
S9+40	3.2mV	900µV
S9+60	80mV	22mV

BANDWIDTH SET TO	----IF BANDWIDTH---- -6dB	-60dB
CW 500Hz	517Hz	825Hz
USB 2300Hz	2303Hz	3573Hz
AM 2500Hz	5970Hz	9005Hz
AM 5000Hz	11420Hz	15190Hz
FM and FM-N	12750Hz	20540Hz

INTERMODULATION (50kHz SPACING) ON USB. BANDWIDTH 2.3kHz (Rx1) 2.8kHz (Rx2)

	---Rx1 PREAMP OFF---		---Rx1 PREAMP ON---		---Rx2 PREAMP OFF---		---Rx2 PREAMP ON---	
Frequency	3rd order intercept	2 tone dyn range	3rd order intercept	2 tone dyn range	3rd order intercept	2 tone dyn range	3rd order intercept	2 tone dyn range
1.8MHz	+25dBm	101dB	+14.5dBm	100dB	+29.5dBm	106dB	+16dBm	101dB
3.5MHz	+28dBm	103dB	+16dBm	101dB	+20.5dBm	100dB	+16.5dBm	102dB
7MHz	+31dBm	105dB	+22dBm	105dB	+21.5dBm	100dB	+12dBm	99dB
10MHz	-	-	-	-	+21.5dBm	100dB	+15dBm	99dB
14MHz	+29.5dBm	104dB	+15.5dBm	100dB	+21dBm	99dB	+11dBm	97dB
18MHz	-	-	-	-	+21.5dBm	100dB	+11dBm	97dB
21MHz	+27.5dBm	102dB	+12dBm	98dB	+22dBm	99dB	+9dBm	96dB
24MHz	-	-	-	-	+18dBm	98dB	+6.5dBm	96dB
28MHz	-	-	-	-	+18.5dBm	98dB	+10dBm	99dB
50MHz	-	-	-	-	+22dBm	99dB	+1dBm	93dB

CLOSE-IN INTERMODULATION ON CW WITH 500Hz BANDWIDTH. PREAMP OFF

	-----Rx1 on 7MHz-----		-----Rx2 on 10MHz-----	
Spacing	3rd order intercept	2 tone dynamic range	3rd order intercept	2 tone dynamic range
1kHz	+3.5dBm	90dB	see text	see text
1.5kHz	+6.5dBm	92dB	see text	see text
2kHz	+23dBm	103dB	see text	see text
3kHz	+29dBm	107dB	+4.5dBm	92dB
4kHz	+29dBm	107dB	+5dBm	92dB
5kHz	+29dBm	107dB	+7.5dBm	94dB
7kHz	+30.5dBm	108dB	+11dBm	96dB
10kHz	+30.5dBm	108dB	+21dBm	103dB
15kHz	+31dBm	108dB	+22.5dBm	104dB
20kHz	+31dBm	108dB	+24dBm	105dB
25kHz	+31dBm	108dB	+25dBm	105dB

TRANSMITTER MEASUREMENTS

	---CW---		-INTERMODULATION- -------PRODUCTS-------	
FREQUENCY	POWER OUTPUT	HARMONICS	3rd order	5th order
1.8MHz	98W	-65dB	-36dB	-40dB
3.5MHz	103W	-65dB	-37dB	-34dB
7MHz	101W	-70dB	-37dB	-34dB
10MHz	102W	-63dB	-36dB	-34dB
14MHz	100W	-75dB	-36dB	-34dB
18MHz	100W	-71dB	-38dB	-34dB
21MHz	100W	-68dB	-34dB	-35dB
24MHz	100W	-70dB	-31dB	-33dB
28MHz	100W	-70dB	-26dB	-38dB
50MHz	96W	-68dB	-33dB	-36dB

	RECIPROCAL MIXING 500Hz BW			---------- BLOCKING PREAMP OFF ----------		
FREQUENCY OFFSET	Rx1 1.9MHz	Rx1 21MHz	Rx2 16MHz	Rx1 2.7kHz ROOF	Rx1 500Hz ROOF	Rx2 2.7kHz FILTER
1kHz	95dB	89dB	AGC blocks	-77dBm	noise limited	-80dBm
2kHz	98dB	95dB	79dB	-45dBm	+15dBm	-43dBm
3kHz	104dB	98dB	83dB	-16dBm	+15dBm	-12dBm
5kHz	112dB	107dB	87dB	>+20dBm	+16dBm	-6dBm
10kHz	117dB	111dB	98dB	>+20dBm	>+20dBm	+2dBm
15kHz	117dB	113dB	104dB	>+20dBm	>+20dBm	+8dBm
20kHz	119dB	115dB	106dB	>+20dBm	>+20dBm	+10dBm
30kHz	119dB	116dB	108dB	>+20dBm	>+20dBm	+11dBm
50kHz	119dB	118dB	110dB	>+20dBm	>+20dBm	+12dBm
100kHz	119dB	119dB	112dB	>+20dBm	>+20dBm	+13dBm

Intermodulation product levels are quoted with respect to PEP.

Microphone input sensitivity: 0.3mV for full output
Transmitter AF distortion: Less than 0.1%
FM deviation: 1.9kHz narrow / 3.8kHz
wide SSB T/R switch speed: mute-Tx 15ms, Tx-mute 4ms, mute-Rx 35ms, Rx-mute 4ms

NOTE:
All signal input voltages given as PD across antenna terminal.
Unless stated otherwise, all measurements made on USB with receiver preamp switched out, 2.3kHz bandwidth.