

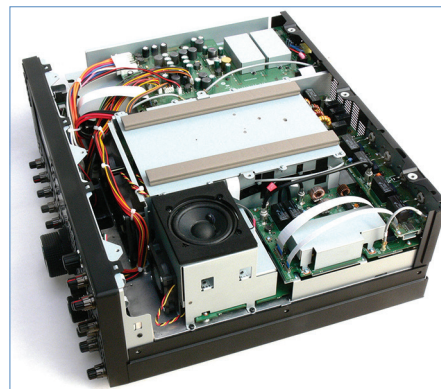
Kenwood TS-990S

New flagship HF & 50MHz transceiver



INTRODUCTION. During the latter months of 2010, Kenwood launched the TS-590S mid-range base station; this was their first new HF transceiver for over seven years. Building on the features of this radio now comes the TS-990S, Kenwood's new flagship top-end radio, offering the very highest in performance and a most impressive level of functions, user control and information display. As a large mains-powered base station delivering 200W output power with dual independent receivers it is targeted as a top-flight DX and contest radio.

BASIC FUNCTIONS. The TS-990S is certainly large, measuring 460mm(w) x 182mm(h) x 449mm(d) and weighs about 25kg. The radio contains dual receivers, main and sub, both tuning 30kHz to 60MHz. They can operate independently over the whole tuning range although the performance is not specified over the full range. The transmitter is enabled on the amateur bands and delivers nominally 200W output power. In the UK, transmit operation on 5MHz is not standard out of the box but can be enabled by Kenwood dealers. A low level



Kenwood TS-990S with cover removed.

drive output is also provided giving about 1mW transmit signal on the 136kHz band as well as transverter drive from any of the HF bands. As with the TS-590S, the low level LF transmit range can be extended to cover 100 – 522kHz with a dealer modification, useful for the 475kHz allocation.

Individual buttons select the bands with a band memory where 1, 3 or 5 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, FSK and PSK, and wide or narrow deviations on FM. A data button selects data mode on SSB and FM when interfacing to PC applications via the sound card and the various shifts and bandwidths are all settable. Modes can be selected automatically according to band plans by setting up a mode-frequency map, and CW transmission whilst on SSB can also be enabled.

The front panel is quite complex but well laid out, with most functions directly accessible from front panel controls in a logical way. The rear panel is fairly uncluttered. There are four antenna sockets and separate in/out sockets to connect a separate receive-only antenna, a separate

receiver, transverter or extra front end filters. The antennas can be named on the panel display. Twin key jacks, one on the rear panel and one on the front, are each configurable for different keying arrangements. A 13-pin DIN connector provides audio and interfacing lines for the datamodes and other accessories, and a separate DIN connector is used for linear amp control. This provides control for both fast QSK linears and older style slower linears that need higher voltage or current control. Menu items allow separate switching characteristics for HF and 50MHz but there is only one linear control line. A dedicated connector interfaces to the AT-300 external ATU but there is no separate direct access to band data. Separate external speaker sockets provide output from the two receivers.

There are two USB-A connectors on the front panel to connect a USB keyboard or external memory and a USB-B connector on the rear, primarily for computer control and audio lines. The usual 9-pin D connector COM port is provided, a LAN Ethernet connection, optical audio input and output lines, a DVI connection for an external display and a socket to connect external analogue meters. The meter connection is identical to the Icom IC-7800 and allows external units such as the LDG DM-7800 to provide dual large S-meters and multiple simultaneous metering on transmit.

The menu system is extremely comprehensive, with over 200 items in the main and sub menus, with every conceivable parameter available for user selection and adjustment. The high resolution display makes access easy, straightforward and unambiguous. Many parameters are adjustable via bargraphs and other forms of graphical displays. Two entirely separate sets of parameters may be stored, configuration A and configuration 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. Configurations and message stores can be saved to external USB memory. Quick access to commonly selected menu items or many other settings including some otherwise inaccessible functions can be assigned to any of the programmable keys. There are two programmable function keys on the front panel, one is rather obscurely placed, and a further two if keys are reassigned. A further eight keys may be accessed via a (home constructed) keypad connected via the rear panel. The up / down keys on the microphone can also be reassigned for this purpose and a further four with the MC-47 microphone. My preference is to allocate one function key to enable TUNE.

There is no microphone provided as standard with the radio but Kenwood have a range of compatible hand and desk

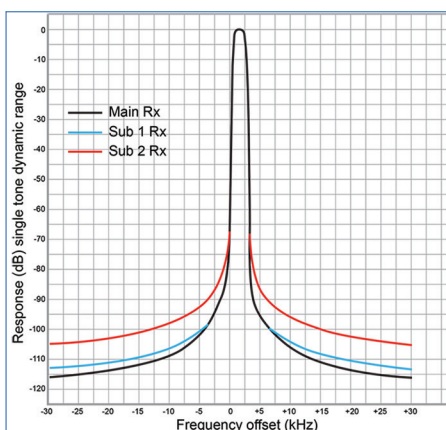
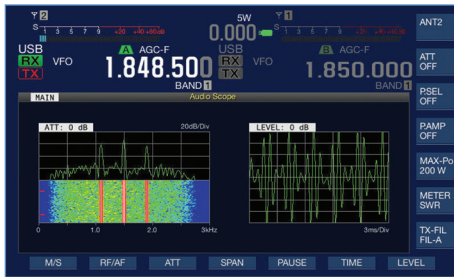


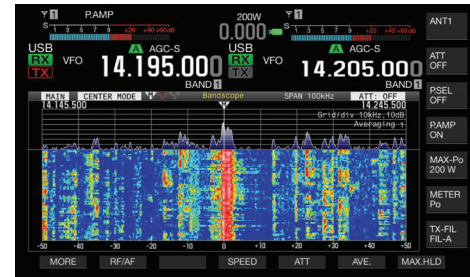
FIGURE 1: Composite selectivity curve on USB.



AF scope screen.



IF filter set-up screen.



Main display with band scope and waterfall.

microphones. The SP-990 external speaker accessory is useful, particularly if the radio is set into a console or has other units on top. It only has a single speaker but includes additional audio tailoring. The instruction manual is huge and although written in a compact style, there are so many features and functions to describe that it runs to nearly 300 pages. Generally it is fairly clear and quite a triumph of writing in itself. At the time of this review, manual revisions were still on-going prior to release of the final version. There are no technical descriptions but circuit diagrams are provided and a separate PC Control Command reference manual is available downloadable from the Kenwood website. Here can also be found updated versions of the instruction manual, firmware upgrades and other relevant software. Another useful website for information is the G3NRW TS-990S Resources Page.

DISPLAYS. The radio uses two full-colour LCD panels that are particularly clear and bright with good viewing angles. The larger 7-inch main display indicates frequencies, S-meters and status messages for both main and sub receivers at all times. The main meter can emulate an analogue style or bargraph format and the sub meter uses a bargraph. The lower part of the display is used for a variety of purposes including a high resolution spectrum scan, message panels for the RTTY and PSK decoders and for menu access and setup, graphical displays used in the various setup screens and memory channel listing. The display is touch sensitive when displaying spectrum scans and will tune the radio to the touched area.

The smaller 3.5-inch sub display is located immediately above the main tuning drive and enables frequencies to be displayed and read with minimum eye movement. It also indicates the audio spectrum overlaid with full details of the channel bandwidth setting, including notch filter placement. On data modes it provides a useful tuning indicator, an X-Y scope on RTTY and a vector scope on PSK.

For retro addicts or those with fond memories of the tuning scales of the past, the smaller display can emulate the dial ring of an analogue mechanical drive and, in SWL mode, the main display can emulate

the string driven ribbon scale of classic short wave receivers such as the Trio 9R-59.

Overall there is far more information presented in such a user-friendly way than by any other radio to date.

RADIO DESIGN AND ARCHITECTURE. The main receiver in the TS-990S follows current practice for high performance radios away from upconversion to a low IF and a suite of roofing filters. The first IF is 8.248MHz with roofing filters of 270Hz, 500Hz, 2.7kHz, 6kHz and 15kHz fitted as standard, selected either manually or automatically according to mode and channel bandwidth. There is provision for a sixth user-fitted filter. The second IF is 24kHz to feed the DSP for all subsequent processing.

The sub receiver adopts the same architecture and circuitry as the TS-590S. On certain amateur bands (160, 80, 40, 20 and 15m) and with bandwidths less than 2.7kHz, the receiver converts to an IF at 11.374MHz with 2.7kHz or 500Hz roofing filters and then to 24kHz for DSP processing. Over the remainder of the tuning range or wider bandwidths, the sub receiver upconverts first to a 73MHz IF with a 15kHz roofing filter, then via 10.7MHz with 15kHz, 6kHz or 2.7kHz filters and finally to 24kHz.

Separate 32 bit floating point DSPs for the main and sub receivers are used to provide IF channel filtering, demodulation, noise reduction, audio processing and AGC functions. On FM, separate FM ICs perform demodulation and pass audio to the DSPs. On this mode the DSP is used purely for audio filtering functions. A third DSP is used by the band scope.

The main receiver uses a switching first mixer and 15 input bandpass filters to cover the total frequency range, relay-switched on the five key bands and diode-switched on the remainder. A tuneable preselector may also be enabled to further reduce out of band signals. The sub receiver uses a quad arrangement of MOSFETs in both first mixer signal paths together with 13 diode-switched bandpass filters. Both receivers use switchable bipolar preamplifiers in the front end with nominally 12dB gain up to 21.5MHz and 20dB gain above and switchable attenuators for really strong signal situations. The local oscillator feed for the main receiver uses a PLL / DDS

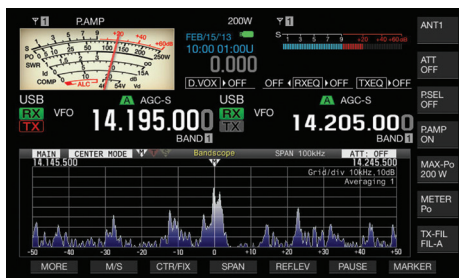
combination at VHF and a divider to achieve low phase noise. A 0.1ppm TCXO reference ensures high stability and accuracy and is available as a 10MHz reference via a rear panel connector to drive other equipment. Alternatively the radio can operate from an external reference. The transmit signal path uses the upconversion sub receiver frequency scheme in reverse.

The radio is solidly constructed with shielded modular units around a substantial diecast frame, well packed there is a lot to this radio. The PA has a large finned heatsink and a total of five internal fans keep the radio cool. These are fairly quiet with variable speed and only operate when the temperature rises, which is rarely under normal use. A single 7.5cm speaker fits in the case top.

RECEIVE FEATURES. The radio is fitted with a 60mm diameter main tuning drive, weighted and smooth in operation. The sub tuning drive is 33mm diameter and also smooth. With 1000 steps per revolution and 10Hz steps, both combine precise tuning with fast frequency navigation. Fine-tuning at one tenth of these rates is selectable and 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, MULTI, 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.

Selecting and swapping between main and sub receivers and split frequency operation are all simply performed. Both the main and sub receivers are equipped with similar functions with separate sets of controls for both receivers and these are logically grouped. With stereo headphones or external dual speakers, the receiver outputs can be kept separate or mixed to any degree (but not of course on the single internal speaker).

RIT and XIT are both provided and an auto-tune feature fine tunes the receiver on clear signals to give the correct CW pitch. There are 120 memory channels with ten for storing programmable scan limits. A host of very friendly memory access and related features are provided including name tagging and scrolling access via the display.



Main display with bandscope.

A separate quick access memory is included, with up to 10 channels stored. The usual comprehensive scanning is provided between frequency limits, across memory channels or groups. Three AGC speeds are selectable, each with a programmable decay time constant; AGC can also be switched off.

RECEIVER FILTERS. The TS-990S is well equipped with channel filtering functions. The IF channel bandwidth can be set over wide limits, down to 50Hz. On voice modes the upper and lower passband edges are set independently (HI/LOW) and on CW and data modes the centre frequency and width are set (SHIFT/WIDTH). SSB and SSB-DATA can use either method. In addition to these settings, the overall shape can be set to sharp, medium or soft. On AM and FM modes the quoted bandwidth is somewhat misleading. On FM it relates to the audio filtered bandwidth; the IF bandwidth is fixed. On AM it also relates to the audio bandwidth after demodulation but the IF bandwidth is filtered to about double this value. The sub display shows the actual set values as well as a graphical overlay on the audio spectrum.

The audio bandwidth can be set overall to narrow, medium or wide and, on CW, an audio peak filter can be enabled. This has three selectable bandwidths 80, 160 or 320Hz and is tuneable across the pitch frequency. In FSK mode, a dual peak audio filter may also be selected. Last, but not least, an audio equaliser is incorporated with six preset profiles or three custom profiles, where each of the 18 channels can be independently adjusted. This is easy to set and graphically portrayed as one of the setup screens.

Three separate sets of bandwidths for each mode may be stored and toggled from a front panel key. This includes IF, AF and roofing filter settings. Separate keys are used for the two receivers.

Four different notch circuits are provided. Implemented at IF is a manual notch with adjustable centre frequency and wide/narrow setting. An IF auto-notch is available on SSB for automatically locating and attenuating a single interfering tone. A separate IF notch, termed Band Elimination Filter, is a manual notch with adjustable depth and stopband. Implemented at audio is a beat cancellation filter for voice modes, often called auto-notch

on other radios. This automatically locates and removes multiple tones with two speed settings, one setting is more effective on continuous beats and the other on intermittent tones.

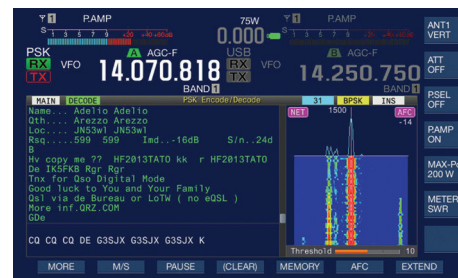
Two separate DSP noise reduction functions are provided that use different algorithms and differ in their effectiveness depending on the prevailing situation. Finally in the armoury for combating interference are two noise blankers. NB1 is a conventional IF gated analogue system and NB2 performs blanking using DSP. Quite a selection to choose from. Again, all functions are duplicated between the receivers, with separate controls.

TRANSMIT FEATURES. The transmitter power output is variable on all modes down to about 1W. The maximum power output can be set separately for each band in 1W steps with different settings for data modes and tune power – very comprehensive. Metering indicates power output, SWR, ALC, compression level, temperature or PA voltage or current. The radio includes a built in auto ATU covering all bands from 1.8 to 50MHz 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 18 selectable profiles similar to the receiver equaliser. On FM, receive and transmit tone decoders and encoders are provided for CTCSS operation and repeater access and these 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 with the drop back delay adjustable from the front panel. An electronic keyer is built in and has various operating modes. It operates over the speed range 4 – 60wpm, with the speed in wpm indicated on the display. The weighting can be varied and made to increase or decrease with speed. Eight message stores are also provided storing up to 50 characters each and can be programmed from the paddle, the MULTI control or from a USB keyboard. Automatically incrementing serial numbers are allowed and messages can be set to repeat after a delay. The message stores are controlled from front panel keys.

DATAMODES. The TS-990S includes fully featured built-in encoders and decoders for RTTY and PSK operation. Unlike many radios where this feature is provided, but rather simplistically, the higher resolution display in the TS-990S together with an external keyboard connected makes real operation much more feasible and enjoyable. The main screen in extended mode allows for 12 lines



PSK decoder screen.

of received data with 43 characters per line and 3 lines of transmit data, together with an FFT scope displaying audio spectrum and a waterfall. In addition, the sub display shows an X-Y scope or vector scope depending on mode. Together these tuning aids are really effective.

PSK operation allows both BPSK and QPSK modes with either PSK31 or PSK63. A host of configurable setups is provided, tone frequencies, shifts, UOS, AFC, tone reversal etc. The text buffer for transmission will store up to 4300 characters and there are eight 70-character message stores for each mode. Incoming messages can be saved to external USB memory.

BANDSCOPE. A versatile spectrum display or bandscope is incorporated into the TS-990S that provides a higher resolution than any other self-contained radio currently available. It also provides a waterfall display, which is often better for identifying weak or keyed signals. The displayed range is 80dB. In centre mode it displays the spectrum centred on the main or sub receiver frequency with spans from 5kHz to 500kHz. In fixed mode it provides scans within each band between presettable limits. Markers indicate the receiver and transmit frequencies and the display can be paused, averaged or maximum-held to assist in different situations. Touching the bandscope display will tune the radio to the touched area but this can be switched off to prevent accidental QSYS.

An audio scope function can also be enabled for the main display. This functions on both receive and transmit and shows the audio waveform, spectrum and a waterfall display of the spectrum. Frequency span, level and sweep time are adjustable.

ADDITIONAL FEATURES. A voice message store is provided, recording short messages for repetitive calls such as CQ calls or recording the receiver audio. There are six channels available for short messages with a total recording time of 100 seconds. Messages can repeat automatically after a time interval. Up to 30 seconds of receiver audio can be recorded per file on internal memory or up to 9 hours if using external USB memory. The voice store can be set to record continuously but retain just the last 30 seconds.



Sub display showing IF bandwidth and notch.

The voice guide provides voice readout 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. If not needed, the voice guide access keys can be used as programmable function keys.

For use with transverters, the display can be set to indicate the transverted frequency up to a maximum of 4.2GHz, with any offset 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 radio.

Other features include clock displays and timers and timed recording, power-on messages and screen saver. The radio is fully supported by Kenwood's suite of software, ARCP-990 and ARHP-990 for full remote operation from a PC or via the internet, and via radio with the Sky Command System II. This includes packet cluster tuning and crossband repeaters.

MEASUREMENTS. The full set of measurements is given in the table. The main receiver sensitivity reduced by 3dB with the sub receiver enabled and then both receivers gave similar results. The sensitivity holds well at LF, achieving -123dBm at 136kHz (preamp on) and only starts to reduce significantly below 100kHz. Sensitivity is reduced by about 18dB over the medium wave broadcast band. The S-meter calibration was similar for both receivers and showed about 3.5dB per S unit; all modes were the same except FM, which was highly compressed.

The rejection of IFs and images for the main and sub receiver downconversion path (SUB1) was typically 70dB to 90dB. For the sub receiver upconversion path (SUB2) these figures were somewhat better, typically around 100dB. Other spurious responses and birdies were very

low, with none of significance. The AGC attack characteristic inserted a hole of up to 10ms in the signal, often seen in DSP implemented systems, which can impair signal copy in noisy situations. The default AGC decay times were quite closely spaced and the user may prefer to widen them. Using a wider roofing filter than necessary can result in close-in desensitisation, as the AGC responds to signals inside the roofing filter bandwidth.

The strong signal performance of the main receiver is top class, with front end IP3 approaching +40dBm on some bands and intermodulation limited dynamic range approaching 115dB in 500Hz bandwidth. The sub receiver is also excellent, with dynamic ranges in excess of 100dB. Close-in, these dynamic ranges hold well down towards the skirts of the roofing filters but reciprocal mixing noise starts to predominate and prevent measurement below about 5kHz. Measurements of blocking show that the front end can handle very strong signals. Blocking was in excess of +20dBm with the preamplifier out for both receivers down towards 5kHz spacing where reciprocal mixing prevented closer measurement. The tuneable preselector reduced sensitivity by around 6dB but had little effect on wideband second order intermodulation, which was already quite reasonable. Inband linearity was very good, but I have seen better.

The reciprocal mixing figures for the main and SUB1 receivers are best on the lower frequency bands; SUB2 sees little variation. The main and SUB1 profiles are somewhat different; the main receiver is best further out but SUB1 is best closer in. For comparison, the 3kHz spaced reciprocal mixing dynamic range figures in 2.5 kHz bandwidth on 7MHz are 93dB for main, 100dB for SUB1 and 87dB for SUB2. These are excellent figures, but have been bettered close-in by some other radios, and allowed measurement of the channel filter bandwidth about 80dB down the skirts. As with most DSP implementations, the filters exhibited a clean response and excellent shape factor. **Figure 1** shows the composite selectivity curve and the effect of reciprocal mixing in the different receiver paths.

On transmit, two-tone distortion products were low and the processor was clean with negligible effect on wideband products. The audio was very clean with low distortion and quite tolerant of high ALC levels and overdrive. The auto ATU reduced power by about 10 to 15%. CW rise and fall shapes were fine, with negligible distortion or character shortening at 40wpm even in full break-in mode. There was a 15ms delay on keying to allow for linear switching. Linear control by relay added a further 15 to 30ms on key-down for slow linears and this results in first character shortening. AM transmit was clean with low distortion.

ON-THE-AIR PERFORMANCE. A first encounter with the TS-990S (or indeed its manual) can seem quite daunting. However, I found that as you get to know the radio it is straightforward, a delight to use and I really appreciated the usefulness and clear information presented on the various display screens. The front panel is quite complex but the controls are well grouped, the tuning smooth and positive and functions easy to access. It takes 45 seconds for the radio to power up and during that time the display can show a start-up message.

The radio performed impeccably on strong and weak signals and in crowded conditions. The filters were excellent, the various notches and noise blankers all performed well. The audio quality using the internal speaker was excellent with good volume and no rattles. I also used the SP-990 external speaker and that gave even better quality. Clean performance extended down to LF with the time-code transmissions and in the AM broadcast bands. The two noise reduction modes were different in the way they transformed the signal. 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 MC-43S hand microphone although a little susceptible to acoustic handling noise. Better still was the quality from the MC-90 desktop unit. The processor was clean and added extra punch. On CW the keying and sidetone were clean and with full break-in it was possible to listen between characters up to around 30 wpm. The relay used for linear switching, if using this method, is rather noisy – particularly in full break-in mode.

I found that the touch screen tuning on the bandscope was not particularly accurate to set, but playing with the calibration routine helped. The frequency you tune from is lost and the ability to allocate an Undo function to one of the programmable keys would be very helpful.

CONCLUSIONS. The TS-990S is an outstanding radio. Its performance is second to none, right up there with the best, but what really sets this radio apart from all others is the level of built-in features, their ease of access and the degree of information presented to the operator. No other radio comes anywhere near the clear display of all operating parameters. However, this does come at a price; it is not a cheap radio and currently sells for around £6600 but I am sorely tempted.

ACKNOWLEDGEMENTS. I would like to express my gratitude to Kenwood Electronics UK for the loan of this radio and to Radioworld Ltd for the loan of the LDG DM-7800 accessory.

KENWOOD TS-990S MEASURED PERFORMANCE

Receiver measurements

All measurements relate to main receiver unless indicated otherwise SUB1 refers to the sub receiver downconversion path and SUB2 the upconversion path

Frequency	---Sensitivity SSB 10dBs+n:n---		-----Input for S9-----	
	Preamp Off	Preamp On	Preamp Off	Preamp On
1.8MHz	0.45µV (-114dBm)	0.11µV (-126dBm)	80µV	20µV
3.5MHz	0.45µV (-114dBm)	0.11µV (-126dBm)	80µV	20µV
7MHz	0.63µV (-111dBm)	0.16µV (-123dBm)	110µV	28µV
10MHz	0.63µV (-111dBm)	0.16µV (-123dBm)	100µV	28µV
14MHz	0.56µV (-112dBm)	0.14µV (-124dBm)	90µV	22µV
18MHz	0.63µV (-111dBm)	0.16µV (-123dBm)	100µV	25µV
21MHz	0.56µV (-112dBm)	0.16µV (-123dBm)	90µV	25µV
24MHz	0.63µV (-111dBm)	0.1µV (-127dBm)	100µV	10µV
28MHz	0.63µV (-111dBm)	0.1µV (-127dBm)	100µV	10µV
50MHz	0.5µV (-113dBm)	0.11µV (-126dBm)	80µV	10µV

AM sensitivity (28MHz), preamp on: 0.63µV for 10dBs+n:n at 30% mod depth
 AGC threshold, preamp on: 0.8µV
 AGC decay time: adjustable 80ms to 3s, see text
 FM sensitivity (28MHz), preamp on: 0.18µV for 12dB SINAD at 3kHz pk deviation
 100dB above AGC threshold for 2dB audio
 Max audio at 1% distortion: 1.9W into 8Ω
 Inband intermodulation products: -45 to -55dB
 output increase
 AGC attack time: see text

S-reading (7MHz)	Input Level USB	
	Preamp Off	Preamp On
S1	5µV	1.4µV
S3	11µV	2.8µV
S5	25µV	6.3µV
S7	50µV	14µV
S9	110µV	28µV
S9+20	1.1µV	280µV
S9+40	11mV	2.8mV
S9+60	110mV	28mV

Intermodulation (50kHz spacing) on USB: bandwidth 2.3kHz (Main and SUB1), 2.8kHz (SUB2)

Frequency	Main Preamp On		Main Preamp Off		SUB1 Preamp Off		SUB2 Preamp Off	
	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	+25.5dBm	108dB	+31.5dBm	104dB	+28dBm	101dB	+27.5dBm	100dB
3.5MHz	+27dBm	109dB	+37dBm	107dB	+32dBm	103dB	+28.5dBm	100dB
7MHz	+32dBm	110dB	+38dBm	106dB	+31dBm	102dB	+30dBm	101dB
14MHz	+32dBm	111dB	+37dBm	106dB	+32.5dBm	104dB	+31.5dBm	102dB
21MHz	+31.5dBm	110dB	+39.5dBm	108dB	+32dBm	103dB	+31.5dBm	102dB
28MHz	+12.5dBm	100dB	+33dBm	103dB	-	-	+30.5dBm	102dB
50MHz	+14dBm	100dB	+35dBm	105dB	-	-	+29dBm	99dB

Frequency Offset	Reciprocal Mixing Phase Noise 7MHz			Transmit Noise 7MHz
	Main	SUB1	SUB2	
1kHz	120dB/Hz	126dB/Hz	113dB/Hz	-96dB/Hz
2kHz	121dB/Hz	131dB/Hz	118dB/Hz	-106dB/Hz
3kHz	127dB/Hz	134dB/Hz	121dB/Hz	-111dB/Hz
4kHz	132dB/Hz	137dB/Hz	123dB/Hz	-114dB/Hz
5kHz	135dB/Hz	140dB/Hz	126dB/Hz	-118dB/Hz
10kHz	144dB/Hz	145dB/Hz	132dB/Hz	-123dB/Hz
15kHz	147dB/Hz	147dB/Hz	134dB/Hz	-128dB/Hz
20kHz	149dB/Hz	149dB/Hz	137dB/Hz	-133dB/Hz
30kHz	150dB/Hz	151dB/Hz	139dB/Hz	-134dB/Hz
50kHz	156dB/Hz	154dB/Hz	141dB/Hz	-135dB/Hz
100kHz	160dB/Hz	156dB/Hz	143dB/Hz	-135dB/Hz

Transmitter Measurements

Frequency	CW Power Output	Intermodulation Products		
		Harmonics	3rd order	5th order
1.8MHz	200W	-70dB	-32dB	-45dB
3.5MHz	208W	-70dB	-40dB	-42dB
7MHz	207W	-72dB	-42dB	-46dB
10MHz	207W	-70dB	-50dB	-44dB
14MHz	207W	-68dB	-42dB	-46dB
18MHz	207W	-75dB	-46dB	-50dB
21MHz	207W	-68dB	-35dB	-45dB
24MHz	207W	-64dB	-31dB	-50dB
28MHz	206W	-66dB	-31dB	-47dB
50MHz	203W	-73dB	-33dB	-49dB

Carrier suppression: <-80dB
 Sideband suppression: <-80dB
 Microphone input sensitivity: 0.2mV for full output
 Transmitter AF distortion: less than 0.1%
 FM deviation: 1.9kHz narrow / 3.6kHz wide
 SSB Data T/R switch speed: mute-Tx 20ms, Tx-mute 5ms, mute-Rx 35ms, Rx-mute 2ms

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.

Intermodulation product levels are quoted with respect to PEP.