Product Review Column from *QST* Magazine

March 1992

The Japan Radio Company JST-135HP MF/HF Transceiver

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Having owned a Japan Radio Company NRD-525 receiver (reviewed in *QST*[1]), I volunteered to review the JST-135HP transceiver knowing full well that I'd probably have a story to tell. A new (to the US ham market) MF/HF transceiver in the $2700 price class, the JST-135HP faces some pretty stiff competition at and somewhat below its price—and four years at the controls of an NRD-525 suggested that the user-interface/feature blend in a JRC-engineered ham transceiver might offer enough surprises to require a reviewer who "speaks JRC." This supposition turned out to be true.

The JST-135HP's basic specifications pretty much bracket what we expect of a 1990s MF/HF transceiver. Specified as capable of full break-in (QSK), VOX and manual TR switching (appropriate to operating mode), the JST-135HP transceives AFSK, AM (USB-plus-carrier transmit, full-carrier USB, LSB or DSB receive), CW, LSB, USB and FM on all ham bands between 1.8 and 30 MHz, and receives these modes from 100 kHz to 30 MHz. It's solid-state, synthesized, computer-controllable (with the addition of an optional interface board and connector), has two VFOs and 200 tunable memories, and can be tuned via knob, **UP/DOWN** buttons (on its front panel and matching hand mike) and keypad. You can control its RF (that is, IF) and AF gain; shift its receiver passband; set its AGC to fast, slow or off; choose various IF receive selectivities, depending on the mode and optional filter installed; toggle and tune an IF notch filter; select one of two noise blankers and vary its blanking threshold; and toggle an RF attenuator during receive. Rear-panel jacks provide I/O for a separate receive antenna; antenna-tuner and amplifier control; and data-communication modems, as well as a low-level transmitter output (typically for use with VHF/UHF transverters). The radio contains a tiny, upward-firing speaker.

A bare-bones JST-135 configured basically as I've just described sells in the $1550 price class. Why does JRC price the JST-135HP transceiver near $2700 and add *HP—h*igh *p*erformance—to its name? Answer: Japan Radio adds to the basic JST-135: a power supply, hand mike, 1-kHz IF filter, high-stability crystal oscillator, bandwidth-control unit, phase-locked AM detector unit, and tracking notch filter unit (and its associated daughter board).

Looking at the options among these that significantly modify the on-the-air performance of the HP version over that of the standard JST-135:

- The 1-kHz (at −6 dB, 3 kHz wide at −60 dB) filter can be selected in **CW NARR**ow and **AFSK NARR**ow reception.
- The bandwidth-control (BWC) board allows the radio's IF passband to be narrowed by up to 800 Hz, in 10-Hz steps, during CW, SSB and AFSK reception.
- The-notch-follow filter board modifies the JST-135's standard IF notch so that it can shift in step with main tuning to keep the notch in place on an interfering signal as you tune the transceiver.
- The phase-locked AM detector (which JRC calls the *ECSS* [*exalted-carrier selectable-sideband*]) board allows phase-locked, selectable-sideband synchronous detection of full carrier SSB and DSB AM signals to minimize selective fading distortion and help reject SSB interference. (See the sidebar for a description of phase-locked AM detection, also known as *synchronous* detection.)

The JST-135HP, then, is a $1550 radio bundled with over $1300 worth of options. In this configuration, does it qualify as a competitive, high-performance radio that offers good value for its price? Let's take a closer look.

Interference-Rejection Features

The first thing I look for in a high-performance radio is the presence and smooth integration of interference-rejection features equal to contest and pileup situations. Here, Japan Radio's IF filter choices fall short. With **BWC** set for wide-open selectivity, the JST-135HP's standard SSB (and wide CW/AFSK) filter (2 kHz wide at −6 dB and 6 kHz at −60 dB, a shape factor of 3) is somewhat narrower than usual for "stock SSB" filtering at −6 dB, and too wide at −60 dB. On-air use confirms this: With the 2-kHz filter selected and BWC wide open, adjacent-signal selectivity is inadequate on SSB; on CW, with the radio's receive pitch set to its factory default (800 Hz), you can hear several hundred hertz of "the other side of zero beat" on signals of moderate and higher strength! The "stock SSB" filtering even of entry-level radios from other manufacturers do better than this; the widest "stock SSB" shape factor derivable from the claimed selectivities of the IC-725, TS-140S and FT-747GX transceivers is *2.3* (FT-747GX, 2.2 kHz at −6 dB and 5 kHz at −60 dB).

JRC's choice of a 1-kHz filter—again, with a 3:1 shape factor—for CW/AFSK narrow reception also puzzles me. With BWC wide open, it's just too wide for serious high-performance use. Hams have long considered 500 Hz a practical *maximum* for CW narrow, and many operators prefer a 250-Hz bandwidth when the going gets tough. In competition-grade radios with high-performance implications, a 1-kHz "narrowest" filter is unheard of.[2]

The JST-135HP's competitors generally use double (sometimes called *cascade*) filtering that allows buyers to install an array of different filters at two IFs (one IF is usually somewhere between 6 and 11 MHz; the other is usually 455 kHz). With the JST-135HP, you can install *one* additional filter (300 Hz, 500 Hz, 1.8 kHz or 2.4 kHz), at 455 kHz—a filter assignable to CW/AFSK or SSB, but not both.

Unlike some of its competitors, the JST-135HP does not allow you to use any

[1]D. Newkirk, "The Japan Radio Company NRD-525 General-Coverage Receiver," Product Review, *QST*, Jul 1988, pp 40-43. This is recommended reading—not because I wrote it, but because the JST-135HP's construction (card cage and motherboard) and basic user interface—including, for instance, its multifunction display and moving-bar S meter—closely parallel the NRD-525's.

[2]Most high-performance radios, including the ICOM IC-765 and IC-781, and the HP variants of the Yaesu FT-1000 and Kenwood TS-950S, include cascaded narrow (500-Hz, and, in some cases, 250-Hz) CW filters as standard equipment.

Table 1
Japan Radio Company JST-135HP MF/HF Transceiver, Serial Number BS1 4312

Manufacturer's Claimed Specifications	*Measured in the ARRL Lab*
Frequency coverage: Receive, 0.1-30 MHz; transmit, 1.8-2, 3.5-4, 7-7.3, 10.1-10.15, 14-14.35, 18.068-18.168, 21-21.45, 24.89-24.99, and 28-29.7 MHz.	As specified.
Modes of operation: AFSK, AM, CW, FM, LSB, USB.	As specified.
Power requirement: 13.8 V dc at 1.5 A (receive) and 33 A (transmit).	Receive, 1.5 A max; transmit, approx 30 A max.
Receiver	*Receiver Dynamic Testing*
Receiver sensitivity (bandwidth not specified): AFSK, CW, and SSB (10 dB S+N/N): 0.1-0.5 MHz, 5 μV (−93 dBm); 0.5-1.6 MHz, 2 μV (−101 dBm); 1.6-30 MHz, 0.31 μV (−117 dBm).	Minimum discernible signal (noise floor) with 1-kHz IF filter: 1.8 MHz, −128 dBm; 3.5 MHz, −132 dBm; 14 MHz, −132 dBm; 28 MHz, −133 dBm.
AM (10 dB S/N): 0.1-0.5 MHz, 16 μV (−83 dBm); 0.5-1.6 MHz, 6.3 μV (−91 dBm); 0.5-1.6 MHz, 16 μV (−83 dBm); 1.6-30 MHz, 2 μV (−101 dBm).	6-kHz IF filter, signal 30% modulated with a 1-kHz tone: 1 MHz, −117 dBm; 3.8 MHz, −120 dBm; 14.2 MHz, −120 dBm.
FM (12 dB SINAD): 1.6-30 MHz, 0.5 μV (−113 dBm).	29 MHz, −113 dBm.
Receiver dynamic range: Not specified.	Blocking dynamic range (1-kHz IF filter):* 3.5 MHz, NL at 121 dB; 14 MHz, NL at 117 dB.
	Two-tone, third-order intermodulation distortion dynamic range (1-kHz IF filter):* 3.5 MHz, 95 dB; 14 MHz, NL at 91 dB.
Third-order input intercept: Not specified.	3.5 MHz, 10.5 dBm; 14 MHz, 4.5 dBm.
S-meter sensitivity: Not specified.	At 14 MHz: S1, 1.7 μV; S9, 37 μV.
CW/SSB squelch sensitivity (1.8-30 MHz): Not specified.	14 MHz, −89 dB.
FM squelch sensitivity: Not specified.	29 MHz, −101 dB.
IF notch filter attenuation: Approx 40 dB.	More than 30 dB.†
Receiver audio output: More than 1 W at 10% distortion with a 4-Ω load.	3.6 W at 10% total harmonic distortion (THD) with a 4-Ω load.
Receiver IF/audio response: Not specified.	Receiver IF/audio bandwidth at −6 dB: SSB, 2356 Hz max, 1312 Hz min; CW narr, 1375 Hz max, 504 Hz min; CW wide, 1882 Hz max, 1062 Hz min.
Transmitter	*Transmitter Dynamic Testing*
Transmitter power output: Adjustable from 10-150 W.	Output power: Min, 6-8 W; max, 151-172 W. Maximum output is typically more than 160 W and varies slightly from band to band).
Spurious-signal and harmonic suppression: Not specified.	Meets FCC regulations. See Fig 1.
Third-order intermodulation distortion products: −38 dBc or better.	See Fig 2.
CW-keying characteristics: Not specified.	See Fig 3.
Low-level transmitter output: 1 V across 50 Ω.	18 mW, fixed level.
Transmit-receive turnaround time (PTT release to 90% audio output): Not specified.	S1 signal, 28 ms; S9 signal, 28 ms; AGC off, 28 ms. (Suitable for AMTOR ARQ.)
Composite transmitted noise: Not specified.	See Fig 4.
Size (height, width, depth): 5.6 × 13 × 15.4 inches; weight, 19 lb.	

*Blocking dynamic range and third-order IMD dynamic range measurements were made at the ARRL Lab standard signal spacing of 20 kHz. *NL* signifies noise-limited dynamic-range measurements.

†Test-equipment limitations inhibit ARRL Lab measurement of notches deeper than about 30 dB.

non-FM filter in any mode. SSB users have only one choice in the stock JST-135HP: SSB **INTER**mediate—the 2-kHz filter. Ironically, AM users get the most options (2, 6 and 12 kHz); FM-mode users can choose between 6 and 12 kHz. Whatever bandwidth options are present, you must step through them (**NARR**, **INTER**, and **WIDE**, or a subset of these) with **BAND WIDTH** < and > keys.

The JST-135HP's relative lack of user-configurable double filtering is a serious setback in a radio in its price class. I say *user-configurable* because the JST-135HP *does* use a form of double filtering (in CW, AFSK and SSB) to implement electronic bandwidth control.[3] (The JST-135HP's BWC board converts signals at the transceiver's 455-kHz IF to 400 kHz for passage through a filter of unknown specifications, and back to 455 kHz. No optional filters, either additional or to replace the filter present with one of a different bandwidth, are available for use in this position.)

Can the JST-135HP's bandwidth control compensate for its overly wide 1- and 2-kHz filters? According to specification, BWC can narrow the 2-kHz filter to 1.2 kHz and the 1-kHz filter to 200 Hz. We measured the JST-135HP's "**BWC** wide open" numbers as 1882 Hz with the 2-kHz filter and 1375 Hz with the 1-kHz filter. But at what shape factor? We can't accurately measure the JST-135HP's −60-dB selectivity, so we took −6 and −30 dB data for comparison. With the 1-kHz IF filter selected and **BWC**

[3]For a description of how electronic bandwidth control (sometimes called *variable bandwidth tuning*, or VBT) works, see G. Collins and D. Newkirk, "Transceiver Features That Help You Beat Interference," *QST*, Mar 1991, pp 16-21. For a discussion of the compromises involved with passband narrowing by means of VBT, see J. Pelham, "Putting Variable-Bandwidth Tuning Back Into Late-Model ICOM IC-751A Transceivers," Hints and Kinks, *QST*, Apr 1991, pp 47-48.

set for maximum bandwidth, the JST-135HP's −6-dB selectivity (IF plus audio response) is 1375 Hz; at −30 dB, it's 1594 Hz. This gives a −30/−6 shape factor of 1.16. When BWC is fully narrowed, these numbers are 504 Hz at −6 dB and 816 Hz at −30 dB, for a shape factor of 1.62. This represents a *40% shape-factor degradation* when you crank the JST-135HP's bandwidth down to about 500 Hz. In terms of IF selectivity, both in the lab and on the air, transceivers competitive with the JST-135HP that are configurable with pairs of SSB-bandwidth and 500- or 250-Hz filters at two IFs leave the JST-135HP's selectivity in the dust. *Electronic bandwidth control is no substitute for high-performance filtering.*

As if this wasn't enough, the JST-135HP's BWC circuitry suffers a fatal flaw: It manufactures spurious signals. With BWC on and adjusted for minimum IF bandwidth, tuning lower in frequency from a strong signal (S9 and higher on the air; considerably weaker under lab conditions) in CW or SSB, you hear a weaker, high-pitched duplicate of that signal between about 1.5 and 2.5 kHz below the real thing (2-kHz IF filter selected) or between about 1.5 and 2 kHz below (1-kHz IF filter selected). During receiver dynamic testing in the ARRL Lab, we sometimes had to change our standard test frequencies a bit to keep these internally generated spurs away from signals we wanted to measure. Adjusting the **BWC** control toward wider-open selectivity shifts the pitch of these spurs—another indication of their source, since adjusting **BWC** does not (and should not) change received-signal pitch.

Tracking Notch Filtering

The JST-135 includes a good IF notch filter. The rig's notch-follow function allows you to command the transceiver, via keypad, to move the notch in step with main tuning. Once you've set the notch to minimize a carrier, turning on notch follow keeps the carrier knocked down through main-tuning variations of ±10 kHz—if the carrier itself doesn't move out of the notch. I found this feature to be most useful during CW reception; in SSB and data modes, I generally tune my radio for proper demodulation and leave it there.

Tuning, Modes and Memories

Frequency/mode agility is next on my list of radio characteristics paramount in high-performance transceivers. Just the presence of a tuning knob and buttons, a keypad and memories doesn't guarantee good frequency agility; *how they're integrated* tells the tale. Especially in contest and DX operation, you need to be able to change bands, frequencies and modes rapidly, non-annoyingly and with few *and logical* button pushes. The JST-135HP combines one of the most velvety tuning knobs I've ever used with a frustratingly clunky, function-key-riddled user interface.

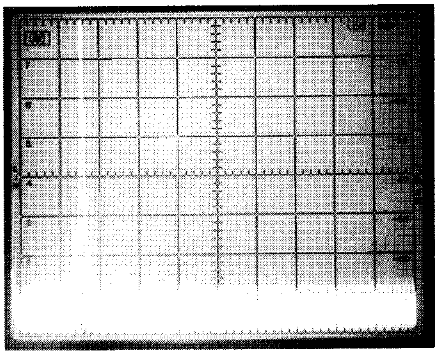


Fig 1—JRC JST-135HP worst-case spectral display. Horizontal divisions are 10 MHz; vertical divisions are 10 dB. Output power is approximately 150 W at 18.07 MHz. All harmonics and spurious emissions are at least 63 dB below peak fundamental output. The JST-135HP complies with current FCC specifications for spectral purity for equipment in its power-output class and frequency range.

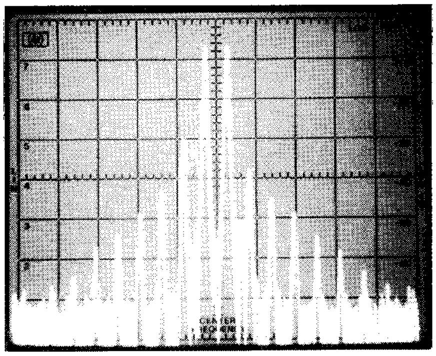
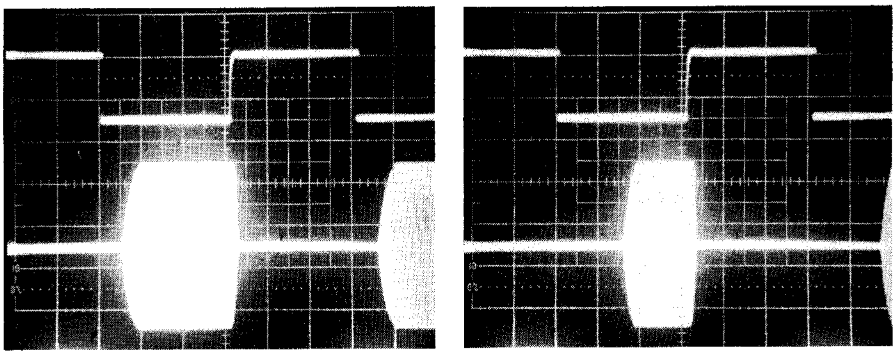
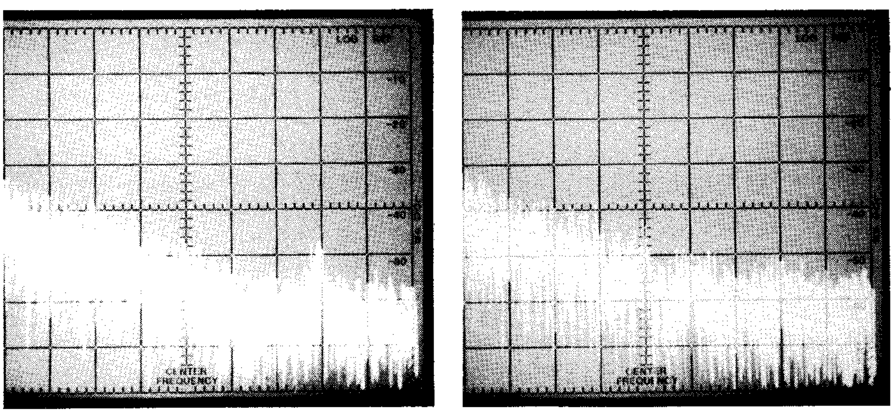


Fig 2—Worst-case spectral display of the JST-135HP transmitter during two-tone intermodulation distortion (IMD) testing. Third-order products are approximately 30 dB below PEP output, and fifth-order products are approximately 43 dB down. Vertical divisions are 10 dB; horizontal divisions are 2 kHz. The transceiver was being operated at 150 W PEP output at 3.9 MHz.



(A) (B)

Fig 3—CW-keying waveforms for the JRC JST-135HP in the semi-break-in mode (A) and the full-QSK mode (B). The upper traces are the actual key closures; the lower traces are the RF envelopes. Horizontal divisions are 10 ms. The transceiver was being operated at 150 W output at 14 MHz. The JST-135HP's CW keying shaping is good, but its full-break-in keying truncates each keyed element.



(A) (B)

Fig 4—Spectral display of the JST-135HP transmitter output during composite-noise testing. Power output is 150 W at 3.52 MHz (A) and 150 W at 14.02 MHz (B). Vertical divisions are 10 dB; horizontal divisions are 2 kHz. The scale on the spectrum analyzer on which these photos were taken is calibrated so that the log reference level (the top horizontal line on the scale) represents −60 dBc/Hz and the baseline is −140 dBc/Hz. Composite-noise levels between −60 and −140 dBc/Hz may be read directly from the photographs. The carrier, off the left edge of the photographs, is not shown. These photographs show composite transmitted noise at frequencies 2 to 20 kHz offset from the carrier.

The designers of other ham transceivers in the JST-135HP's class consider frequency/mode agility important enough to design in dedicated buttons for mode, VFO A/B, A = B, split, memory store, memory recall and so on. On the JST-135HP, only two of these (VFO A/B and transmit/receive-frequency check) get their own unambiguous keys: **F1/F2** for VFO A/B, and **T.F/R.F**, a momentary button that lets you check (and, while receiving, change) the status of "the other" VFO during split operation.

Changing modes with the JST-135HP involves poking one of the two **MODE** keys (< or >) and watching the multifunction display as you step through AFSK, CW, USB, LSB, AM, and FM. This function "wraps"; pressing > with FM takes you back to AFSK, for instance.

As clunky as < and > bandwidth and mode keys may seem, some JST-135HP user-interface features are even clunkier. Ever see someone grimace and hold their breath when switching from **AGC FAST** to **SLOW**? With the JST-135HP, you have to step through **OFF** first! If you want to equalize the JST-135HP's VFOs, you must first press one of the radio's three function keys (**FUNC/HAM**—the others are **CHANNEL** and **FREQ**; there's no default—the function key you pressed last remains in effect) so that pressing the keypad's **4** doesn't start entering an operating frequency (**FREQ** mode) or memory-channel number (**CHANNEL** mode). Likewise for operating split, toggling VOX or—gasp—selecting a tuning speed! The JST-135HP allows you to tune with a variety of step sizes, but choosing among them takes *5 to 10 seconds of control fiddling*. Unlike some transceivers, the JST-135HP main-tuning circuitry doesn't switch to a higher frequency-versus-revolution rate as you spin the dial faster. The transceiver's **DOWN** and **UP** buttons help somewhat.

As an example of the confusion created by the JST-135HP's function keys, consider JRC's choice of assigning display **DIMMER** as an alternate function to the keypad's numeral **1**. Users wanting maximum band/VFO agility tend to keep the radio in **FUNC/HAM** mode, which allows quick access to the radio's **F1 = F2** and split functions, and allows the radio's **UP** and **DOWN** buttons to step (tiresomely) through ham bands. In **FUNC/HAM** mode, pressing the keypad's **1/DIMMER** button cycles the JST-135HP through its three display-brightness choices (off, bright, dim). Now: It's late evening and you've already dimmed the display, leaving the radio in **FUNC/HAM** mode. A PacketCluster spot comes in for 14.005 MHz, so you decide to jump there with the keypad. You press **1** and the radio's display and annunciator LEDs go dark—*arrgh!* To recover, you'll need to press **1/DIMMER** *twice more* to turn the display back on and dim it, press **FREQ** and *then* start entering your frequency. But wait, there's more: If, in keying rapidly, you got as far as the *4* in *14* before stopping at the sight of a dark radio, *you also inadvertently equalized VFOs F1 and F2* (**4** serves as **F1 = F2** in the **HAM/FUNC** mode), losing whatever information was present in "the other" VFO at the time!

Then there's the question of why anyone would want to turn off the display in the first place. . . .

The JST-135HP routinely requires you to press function keys to do things operated via dedicated buttons on other transceivers. These annoyances seem even greater when you see significant panel space and control size dedicated to secondary, tertiary or set-and-forget features—QSK on/off, noise-blanker trigger level, squelch, pause level (stops scanning at a threshold different from that set by **SQUELCH**), and VOX sensitivity and delay—when smaller, dedicated controls for *primary* features would make life with the JST-135HP a *lot* easier. Incidentally, going from keyed VOX to full QSK operation requires pressing only one button, but when you press that button again to leave QSK mode, you must press *two more* buttons to return to keyed-VOX mode.

Using It

The JST-135HP meets its published specifications. It transmits clean SSB at 150 W output. Using the supplied microphone, I couldn't drive the radio's ALC metering into the forbidden red zone even with **MIC** up full. (The JST-135HP's mike-connector pinout is the same as Yaesu's, by the way.) The JST-135HP includes audio speech processing adjustable for up to 20 dB of compression. Properly adjusted, it punched up my voice quite usefully without objectionable distortion. Disappointingly, though, the JST-135HP doesn't transmit with phase-noise cleanliness we expected of the presence of direct digital synthesis (DDS) in its signal-generation scheme even though the *Operation Manual* characterizes the transceiver as embodying "high C/N performance and high-speed transmit/receive switching."

This shortcoming also manifests itself as noise-limited receiver dynamic range—a characteristic we rarely see in modern MF/HF radios tested in the ARRL Lab. Capable of clean, wide-band receive audio, however, the JST-135HP receives CW and AM with near-crystalline clarity. Its SSB reception is marred somewhat by what sounds like simultaneous heterodyne and envelope detection in the radio's active "product" detector; perhaps relatedly, I sometimes heard IMD between strong in-passband CW signals with BWC wide open.

I've mentioned the JST-135HP's quirky selectivity and user-interface engineering; you're up against these during even the most casual bandscan. The radio has other characteristics anyone considering spending $2700 for a high-performance radio ought to know about:

The JST-135HP's CW QSK so severely truncates transmitted code elements that its full break-in is almost a non-feature. Feeding the JST-135HP a string of dots and increasing their speed, we eventually reached a point—at about 20 ms per dot, roughly equivalent to 50 WPM—where *every other dot disappeared*. It turns out that JRC knows about this problem and revised the radio's software to improve QSK keying. The keying photos in Fig 4 were taken after we installed the PROM containing the latest software. The new software eliminates the lost-dot syndrome, but as the photos show, it doesn't completely fix the radio's QSK keying. (JST-135 and -135HP owners can contact Paul Lannuier, N2HIE, at JRC's New York office [tel 212-355-1180] for the replacement PROM.)

The JST-135HP *Operation Manual* states that "split operation is not possible when transmit VFO is set to CW mode, but receive mode is not set to CW, nor when full break-in is attempted between VFOs set to different bands." This is incorrect. Our test JST-135HP actually *can* work cross-band split in QSK CW—but the results are lousy. Setting the radio for 18-MHz receive and 10-MHz transmit and keying the '135HP sounded okay *in the radio's sidetone monitor*—but a second receiver told the true story: I was sending clicky, chirpy CW at 10 MHz and horrendous choppy clicks at 18 MHz. I think JRC should disallow such operation in firmware rather than writing around it in the manual.

The JST-135HP doesn't remember, band by band, what mode and frequency you last used on a given band. Competitive radios in this price class do, under the name *band-stacking registers* or its equivalent. Memories are no substitute for this feature.

You can set the JST-135HP's CW offset and BFO pitch, *but not its sidetone pitch*, to values from 200 Hz to 1.5 kHz. The radio's sidetone pitch matches its CW-offset/BFO-pitch default (800 Hz). During CW reception, you can get close to zero beat regardless of the offset/BFO pitch selected by pressing the radio's **METER** switch, setting the BFO to IF center. I consider this CW-spotting approach *distinctly inferior* to tuning incoming signals to the sidetone pitch. The JST-135HP receives CW as LSB; that is, tuning the radio lower lowers received-signal pitch.

The JST-135HP's AGC pops *very noticeably* at the onset of strong signals. This is common in receivers that derive AGC from detected audio, but the JST-135HP, like all other modern radios, uses IF-derived AGC. One JST-135HP user who's listened to every major transceiver made in the last 10 years termed the AGC "horrific" and the worst he's heard in a modern radio.

In the AFSK mode, the JST-135HP's frequency readout displays f_0—that is, the imaginary center frequency between mark and space for 170-Hz-shift signals. Unlike the "switch to LSB and feed in the inverted

Synchronous AM Detection

The two radios reviewed this month include an AM-receive feature generically known as *synchronous detection*. What is this feature and why is it a fine thing?

Since the earliest days of AM radiotelephony, the standard means of detecting a full-carrier AM signal was to *rectify* that signal in a diode or other nonlinear circuit element. This mixes the carrier with the signal sidebands and heterodynes them back to audio.

Especially in its simplest (diode) form, rectification detection is hard to beat for low parts count. And if the incoming signal's carrier and sideband(s) arrive at the detector in the same amplitude and phase relationship they exhibited when they left the transmitter, the resultant audio can be quite clean.

The snag with AM signals propagated by skywave, or a combination of groundwave and skywave, is that the amplitude and phase relationship between the carrier and sideband(s)—even among different portions of *one* sideband—undergo *constant variation* with fading. Different portions of the signal fade at different rates, and/or to different depths; fading effects sweep through the signal with time. We call this *selective fading*. With rectification detection, it sounds awful.

For shortwave and long-distance mediumwave listeners, selective fading sounds worst when it reduces carrier strength—sometimes by several tens of decibels—as often as several times each second. Hold your ears: Rectification-detection radios usually produce a blast of distorted audio and noise with each carrier trough as their AGC increases gain. *Auggh!*

Switching a radio to SSB and tuning the signal carrier at zero beat banishes much of selective fading's effects because the radio BFO substitutes for the carrier whether the carrier comes or goes. Snag: You have to tune your radio *just right* or music and voices sound weird (and get weirder, if your radio and the transmitter drift relative to each other). And SSB filters make broadcast audio sound like telephone audio, which lessens the pleasure of broadcast listening.

Synchronous detection fixes this by *phase locking* your radio's BFO to the incoming signal carrier. Within limits, and depending on its design, a sync detector's phase-locked loop can compensate for signal drift and receiver tuning. Music and speech stay at their proper pitches, and the receiver BFO supplies a local demodulating carrier even in carrier troughs. Appropriately applied, synchronous detection can even (by means of RF and AF phasing) select sidebands without narrow IF filtering. Of the radios reviewed this month, the JST-135HP does this. The Drake R8 uses IF filtering for sync-AM sideband selection, but doesn't limit you to SSB-class IF filtering. Each method has strengths and weaknesses.

Arguably the best sync-AM detector currently available to consumers in mass-market MF/HF gear is that in Sony's ICF-2010 portable receiver. The ICF-2010 (which, by the way, selects sidebands by phasing during AM-sync reception) stays locked even during very deep carrier troughs. The JST-135HP and R8 both lose lock several to many times per minute even when tuned to strong, slowly fading signals. In my opinion, the JST-135HP loses lock far more often than the R8, which, aside from its occasional growly "unlocks," sounds smooth as velvet. To equal or beat the ICF-2010, both radios need to stay locked much farther into carrier troughs and lose lock a lot less often. The JST-135HP needs to better ignore signals more than a few hundred hertz from the desired signal's carrier.

Synchronous AM detection is *the* way to receive fade-prone AM. I'm pleased as Punch to welcome the sync-AM issue to *QST*'s Product Review column, and I hope that all ham radios featuring AM-mode reception will one day include first-rate synchronous AM detectors as standard. In the meantime, get a listen to sync-AM-detected shortwave if you can; it will amaze you.—*David Newkirk, WJ1Z, Senior Assistant Technical Editor*

tones" data-communication technique commonly used by hams at MF/HF, the JST-135HP does not invert modem tones during AFSK operation. The JST-135HP cannot itself produce FSK or AFSK; your modem must provide the AFSK audio. A nice touch: You can mute audio from the radio's **MIC** input by applying a positive voltage to an **ACCESSORY** jack pin.

The JST-135HP **ATT** button toggles a 20-dB attenuator, yet critical MF/HF operation sometimes requires more attenuation, sometimes less. Competitive high-performance radios generally include multiple attenuation steps.

The JST-135HP does not include a dedicated RIT control and RIT frequency subdisplay; instead, pressing the **RIT** button makes the main tuning knob vary the receive frequency by ±10.00 kHz and changes the display to indicate only this offset (the operating-frequency display disappears). Pressing **RIT** again deselects RIT but leaves the offset "remembered." (You can clear the offset to zero during RIT operation by pressing the keypad's **CLR/PRI** key.)

A few other notables: The JST-135HP's moderately noisy fan cycles even during receiving periods at room temperature. An internal CW keyer is neither standard nor available as an option on the JST-135HP. The JST-135HP's frequency/memory system cannot memorize splits, nor does it allow split operation based on all possible combinations of VFOs and memories. The radio's memory and frequency-sweep scanning functions include priority monitoring of memory channel 0. The JST-135HP includes no transmit-offset tuning (XIT) aside from that afforded by operating split.

The JST-135HP allows you to set positive and negative repeater offsets of *0 to 30 MHz* via front-panel commands. Installing and selecting an optional tone-squelch board (not tested) lets you transmit the tone of your choice (continually or tone-burst, your choice) on FM. When you enable this function (**TSQ**) and select FM operation, the JST-135HP receiver won't unsquelch on received signals that don't include the tone you've set.

The JST-135HP's phase-locked, selectable-sideband AM detector, which selects sidebands by means of AF/RF phasing instead of the radio's IF filtering, is almost there—*almost* because it loses lock occasionally even during reception of strong, slowly fading shortwave signals; because its unnecessarily wide capture bandwidth sometimes lets it try to lock onto carriers *several kilohertz* away from a strong carrier it's already locked onto; and because the JST-135HP's control software doesn't remember that you've selected synchronous AM when you toggle VFOs or store a sync-AM frequency in memory. (VFO-flip out of sync-AM reception and back again, and you're listening to the radio's non-sync AM detector.) Via the radio's **PHONES** and speaker outputs, you can listen to upper- or lower-sideband sync-AM audio; simultaneous, separate USB and LSB AM-sync audio is available at the radio's rear-panel **ACCESSORY** jack.

The JST-135HP does not include a means of monitoring, at IF or RF, the actual quality of its transmitted signal—a drawback in any radio that includes speech compression, and a glaring omission in a radio of this price class.

JRC specifies the JST-135HP's **EXCITER OUT** jack as supplying 1 V RF across 50 Ω (50 mW into 50 Ω). Power output at the JST-135HP's **ANT** jack is disabled when **EXCITER OUT** is selected by means of one of the radio's many user-defined functions.

The JST-135HP's **LINEAR AMPLIFIER** jack carries ALC and relay-contact amplifier control lines (voltage/current ratings unspecified), as well as logic lines specific to controlling JRC amplifiers.

Outfitted with its optional RS-232-C computer-control board, the JST-135HP can transceive with JRC's NRD-525 receiver (but not with the newer NRD-535).

The JST-135HP's supplied documentation is succinct and generally solid, if brusque; a service manual is also available. The radio's *Operation Manual* falls short in its incomplete and misleading description of how to set User Definition functions (BFO pitch, 10-Hz display toggle, **EXCITER OUT** enable, and so on). You're told that you can either dial these in with the tuning knob or use the keypad. In fact, *only* the tuning knob selects functions 1 through 14 and *only* the keypad selects functions numbered 21-27 and 169. Snag: The display does not echo (display your keypad entries) as you key in User Definition function numbers—until, that is, you press **ENTER**. In the CPU-reset mode, only the keypad selects CPU-reset enable—but hitting the number you want (0 = reset disabled, 1 = reset enabled) doesn't echo your choice as entered and immediately dumps you out of User Definition set mode. So you have to reenter User Definition set mode to determine if your choice really took!

If you want to reset the CPU, you have to choose 1 at function 169, *then turn the radio off and back on*, to perform the reset. There's more: Resetting the CPU returns the radio to its optionless factory-default condition, so you must then enable the appropriate non-default User Definition functions one by one. (The *Operation Manual* mentions this only cryptically.) Until you do this, BWC and the notch won't work, and you can't access the 1-kHz IF filter.

The JST-135HP Question

Does the JST-135HP qualify as a competitive, high-performance radio that offers good value for its price? In my opinion, no. The options JRC bundles with the basic JST-135 don't improve its on-the-air utility to a level comparable with competition-grade radios *designed from the start* to sell in or near its price class. Certainly, the JST-135HP can more than hold its own in conversational and casual CW contesting, SSB and data operation—but hams generally don't (and *needn't*) spend $2700 for a conversation and casual contesting box.

I think the basic JST-135 platform needs work: Its entire front panel and user interface need rethinking and redesign to dedicate more (and more appropriately sized) controls to frequency/band/mode agility, and AGC control. Its basic and not-so-basic radio performance (QSK, blocking dynamic range, composite noise, IF filtering, AGC attack and RF attenuation) need improvement to put them on par with other radios, even in the price class represented by a stripped-down JST-135. Short of such improvement, I can recommend the JST-135HP only to JRC connoisseurs and those who need the special functions (notch follow, synchronous AM reception, USB-only AM transmit, and so on) of which only the JST-135HP is capable.

I thank Rus Healy, NJ2L; Mark Wilson, AA2Z; and Larry Wolfgang, WR1B, for contributing to this review.

THE DRAKE R8 SHORTWAVE RECEIVER

Reviewed by Jim Kearman, KR1S

The R. L. Drake Company made a name in Amateur Radio with a series of innovative receivers, starting with the Model 1A in 1958 and culminating in the highly rated R7A in the 1980s. Then, as quickly as they came on the scene, Drake receivers disappeared from the market. The company decided to explore the home-satellite-TV market. Now, with the R8, Drake is once again causing a stir in Amateur Radio and SWL circles.

Drake's R8 is as much a departure from contemporary communications receivers as the Model 1A was almost 35 years ago. Compared with other modern receivers, the R8 is Spartan in appearance. Behind the barren front panel, however, lurks a sophisticated receiver.

Overview

The R8 can receive CW, FSK, SSB and AM signals from 100 kHz to 30 MHz. IF bandwidths of 500 Hz and 1.8, 2.3, 4 and 6 kHz are standard. No optional IF filters are available for the R8. The R8 IF filters hark back to the models 1, 2 and early R4, as they are LC tuned circuits, not crystal filters. Crystal filters have gotten more expensive over the years (is the world running out of quartz, too?), and apparently LC filters are now more cost-effective.

Some receiver users claim that LC filters provide better audio response for listening to broadcast stations. From a performance standpoint, I wouldn't have known the R8 had LC filters if I hadn't read about them in the *Owner's Manual.*

You can tune the R8 via its tuning knob, up/down buttons or its keypad. The day of the black-box receiver with nothing on its front panel is here, and Drake is obviously planning to take the R8 in that direction (it features a serial-interface connector to allow computer control of most functions, although software for this function, mentioned in the manual as a planned option, was not available at this writing). Soon, you'll be tuning your receiver from your computer keyboard or a logging program tied to PacketCluster. The R8's tuning knob reflects this new era. It's lighter and smaller than I'd prefer.

Going to the PROM

Beneath the R8's tuning window is a row of six push-button switches. When the receiver is turned on, their functions become apparent (their labels are part of the multifunction display). The entire row can be "shifted" to perform an additional set of six functions. You select the operating mode with the button farthest to the right. One button for all those modes? Yes—you press and release this button to cycle through the six mode selections (AM, FM, CW, RTTY, LSB, USB). Mode selection is in one direction only: to go from USB to LSB you have to punch the button five times. Even though this is a "soft-touch" button, it's still not as quick or convenient as separate buttons.

While you're punching this button on the review radio, other things are happening on the display. The bandwidth, AGC and RF indicators are changing too! Welcome to PROM Night. The receiver's microprocessor was programmed to automatically select what the designers considered the best bandwidth, AGC time constant and tuning rate for each mode. "Wait a minute!" you say. "This is a free country, and I don't want to listen to CW with a slow AGC time constant." Okay, okay, take it easy. You can change bandwidth and AGC time constant, and even turn on the preamplifier (above 5 MHz). If you want to listen to the 40-meter Novice/Technician subband at night with the bandwidth at 6 kHz, AGC

Table 2

Drake R8 MF/HF Communications Receiver, Serial Number 10400065

Manufacturer's Claimed Specifications	***Measured in the ARRL Lab***
Frequency range: 100 kHz to 30 MHz.	As specified.
Modes of operation: AM, CW, FM, LSB, RTTY, USB.	As specified.
Power requirements: 100, 120, 200 or 240 V ac ±10% at 40 W, or 11-16 V dc at 2 A max.	At 13.8 V dc: 1.48 A at min audio output; 1.51 A at max audio output, 1.80 A at max audio output with S9 signal; ac current drain not measured.
Sensitivity	
CW and SSB (10 dB S+N/N, bandwidth not specified): 0.1-1.5 MHz, 1 μV (−107 dBm); 1.5-30 MHz, preamp off—0.5 μV (−113 dBm), 1.8-30 MHz, preamp on, 0.25 μV (−119 dBm).	Minimum discernible signal, 500-Hz filter: *Preamp off* / *Preamp on* 1 MHz: −122 dBm / N/A 3.5 MHz: −135 dBm / −139 dBm 14 MHz: −135 dBm / −139 dBm 28 MHz: −135 dBm / −138 dBm
AM (10 dB S+N/N, test signal 30% modulated with a 1-kHz tone, bandwidth not specified): 0.1-1.5 MHz, 3 μV (−97 dBm); 1.5-30 MHz preamp off—1.5 μV (−103 dBm), 1.5-30 MHz, preamp on, 0.8 μV (−109 dBm).	Test signal modulated 30% with a 1-kHz tone, 6-kHz filter: *Preamp off* / *Preamp on* 1 MHz: −83 dBm / N/A 3.8 MHz: −109 dBm / −113.5 dBm 14.2 MHz: −105 dBm / −117 dBm
FM (12 dB SINAD, bandwidth not specified): 0.5 μV (−113 dBm) from 1.5-30 MHz.	12-kHz filter, −101 dBm (preamp on), −109 dBm (preamp off) at 29 MHz.
Dynamic range: 90 dB or more at 20 kHz signal spacing (type and bandwidth not specified).	Blocking dynamic range:* Preamp off—3.5 MHz, NL at 123 dB; 14 MHz, NL at 118 dB; preamp on—3.5 MHz, NL at 112 dB; 14 MHz, NL at 114 dB. Two-tone, third-order intermodulation distortion (IMD) dynamic range:* Preamp off—3.5 MHz, 94 dB; 14 MHz, 90 dB; preamp on—3.5 MHz, 93 dB; 14 MHz, 87 dB.
Third-order input intercept: At least 5 dBm with 20-kHz signal spacing.	Preamp off—3.5 MHz, 6 dBm; 14 MHz, 6 dBm; preamp on—3.5 MHz, 0.5 dBm; 14 MHz, −8.5 dBm.
Notch filter attenuation: 40 dB or more from 0.5-5 kHz.	More than 30 dB.†
S-meter sensitivity: Not specified.	For S9 reading at 14 MHz, 60 μV (preamp off); 20 μV (preamp on).
Squelch sensitivity: Not specified.	12-kHz filter, SSB, −115 dBm min; FM, −106 dBm min.
Receiver IF/audio response: Not specified.	Receiver IF/audio bandwidth at −6 dB: 6-kHz filter, 5180 Hz; 4-kHz filter, 4072 Hz; 2.3-kHz filter, 3125 Hz; 1.8-kHz filter, 2519 Hz; 500-Hz filter, 803 Hz.
Audio output: 2.5 W or more at 10% distortion into 4 Ω.	3.6 W at 10% total harmonic distortion (THD) into 4 Ω.
Size (height, width, depth): 5.25 × 13.1 × 13 inches; weight, 13 lb.	

*Blocking dynamic range and third-order IMD dynamic range measurements were made at the ARRL Lab standard signal spacing of 20 kHz. *NL* signifies noise-limited dynamic-range measurements.

†Test-equipment limitations inhibit ARRL Lab measurement of notches deeper than about 30 dB.

off and preamplifier on, that's your undeniable right. Most of the time, though, I found the default parameters to my liking. Yes, it took a while to get used to mashing the buttons to get what I wanted, sort of like getting used to a new microwave oven or VCR remote control.

Because many R8 users complained to Drake about the radio's automatic return to its default AGC, selectivity and tuning-rate selections every time the mode was changed, they revised the software to return the receiver to the last set of parameters selected on a given mode the next time you change to that mode. All R8s built since the fall of 1991 include the new software. Owners of earlier R8s can purchase the replacement EPROM, which is easy to replace with the instructions Drake provides, for about $13 plus UPS shipping charges (contact Drake for details). Other details of Drake's latest software include allowing preamplifier use down to 1.8 MHz, provisions for aborting a direct-frequency-entry operation, preprogramming of the lower ham-band edges, WWV/WWVH frequencies and popular shortwave broadcast frequencies in 20 of the memories, programmable tuning steps per mode (10 Hz with 10-Hz display resolution, 10 Hz with 100-Hz resolution and 100 Hz with 1-kHz resolution). Based on these changes, you can easily tell whether your radio has the updated or the original software. The new software is definitely worth buying if you want the best flexibility and operating pleasure from your R8.

One place Drake *could* have used the microprocessor to help out—but didn't—is in sideband selection as you pass 9 MHz. According to Amateur Radio tradition, lower sideband (LSB) is used below 9 MHz, and upper sideband (USB) is used above. The current crop of amateur transceivers knows this. So, if you wanted to use the R8 as a second receiver during a sideband contest, you'd have to manually switch sidebands. During a contest, for example, you might prefer to use a selectivity of 1.8 kHz. The default SSB bandwidth is 2.3 kHz. Moving from 20 meters to 40 meters then, requires you to:

1) Retune the receiver using your preferred method.

2) Press the **MODE** button five times to go from USB to LSB.

3) Unless you've already set the SSB bandwidth to 1.8 kHz, press the **BW** button five times to go from 2.3 kHz to 1.8 kHz bandwidth.

You probably won't find R8s in use at serious contest stations!

Other selections available from the bank of buttons are VFO A/B (actually two easily selected, tunable memories), three input selections (two antennas and a converter), preamplifier/attenuator, noise blanker, timer, notch filter, tuning-step rate and dial lock. The timer works with an internal clock, which displays the time while the receiver is off. (You can also view the clock while the receiver is on.) The timer can switch an external circuit—to turn on a tape recorder, for example. The switching circuit *cannot* handle ac line voltage; it's limited to 30 V dc at 1 A.

Using the R8

The first night I used the R8 at home, I started by listening on the ham bands. After wrestling with the buttons a few times I realized the receiver was oriented toward broadcast listening, not Amateur Radio. It was just about sunset, so I headed for the 49-meter shortwave broadcast band (near 6 MHz). I wanted to try out the R8's vaunted synchronous detector, which is intended to improve AM reception with fading signals (see the sidebar on page 71, which describes this feature). I tuned in a rapidly fading broadcast station. Its signal strength varied between S3 and well over S9 about once a second, with the expected audio distortion every time the carrier took a dive. You'd have to *really* want to hear this station to hang in through all that noise! I pressed the **SYNCHRO** button to turn on the synchronous detector. Instantly, the distortion stopped and the signal became not only readable but pleasant to copy. I was impressed!

You can't tune the R8 with the synchronous detector on; it automatically switches off if you bump the tuning knob or switch from AM to another mode. It's easy to enable the synchronous detector, though, and it easily locks onto a signal 2 or 3 kHz away. Lock time depends on signal strength and how close to the carrier frequency you have tuned the receiver. It pays to tune accurately: If you're on the right frequency, the detector locks in almost immediately; otherwise it can take several seconds to synchronize. During this time you hear a heterodyne slowly decreasing in pitch.

Switching bandwidths and adjusting the **PASSBAND OFFSET** control (front-panel knob) allowed me to knock out an interfering adjacent station. In the review R8, a low-level, hummy spur sometimes audible in the receiver audio varies with this control's setting. Because this is present regardless of band and mode, it seems to occur in the IF chain. But the spur level is low enough that you might not notice it at all unless you're adjusting the **PASSBAND OFFSET** control on a quiet band while listening to a relatively strong signal that suppresses band noise. I consider this a minor problem.

The R8's synchronous detector replaces the transmitted carrier and only requires one sideband for detection. By offsetting the passband it's possible to hear sideband audio higher than 5 kHz. Unfortunately, most shortwave broadcast bands are too crowded to allow frequent use of this luxury—but you can switch to the R8's 4, 2.4 or 1.8-kHz filter if necessary. The R8's notch filter effectively reduces heterodyne interference.

The internal speaker is typical of other internal speakers I've heard. Use it to confirm your receiver works when first unpacked, then forget it. I used the R8 with a variety of external speakers, stereo headphones and even my stereo system (the R8 has two line-level audio outputs on its back panel). As a matter of fact, if I owned an R8 I'd probably leave it connected to my stereo! Its no-nonsense front panel blends well with modern audio/video equipment. You probably wouldn't be embarrassed at having this radio in your living room.

Although I found the R8 cumbersome to operate on the ham bands, I did spend time using it there. The radio's 500-Hz selectivity is fine for tuning the CW subbands and copying weaker signals. My transceiver uses a pair of 500-Hz crystal filters. I used a coaxial switch to transfer the same antenna between the two radios. Using only your ears to compare radios is an unscientific but practical way to detect differences in performance. These differences are obvious to the user, too, not just to the test equipment! One thing worthy of note is that the R8 has a mild AGC attack problem that's most pronounced with strong CW signals and fast AGC. The AGC pops at the onset of each keyed element, making copying such signals fatiguing. Slow AGC and weaker signals help, but the true fix would be improved AGC attack characteristics.

The R8 does not have an external BFO pitch control. The factory-default BFO offset from the IF provides a beat note of about 700 Hz. I used the **PASSBAND OFFSET** control to shift the IF over about 200 to 300 Hz. That way I could copy CW at the pitch I prefer, 400 to 500 Hz. If I tried this trick with my transceiver I wouldn't be able to zero beat the station I was calling. (WJ1Z: The R8 is the only communication-quality MF/HF radio new to the amateur market since the early 1980s that displays CW frequencies correctly only when the radio is tuned *to zero beat* instead of the factory-default receiving pitch (700 Hz). In 1992, a 700-Hz display error when listening to correctly tuned CW on a 10-Hz-display radio is unacceptable. I think this flaw could be corrected in software, and I encourage Drake to do so. [As for a pitch reference—being a receiver, the R8 includes no sidetone capable of serving as a transfer oscillator, of course—how about setting the radio's keypad beep oscillator to 700 Hz and allowing it to be continuously keyed for CW frequency measurements with a keypad button?])

On all modes, including SSB and CW, the R8's tuning rate is just about right. I really dislike the tiny tuning knob, though; scanning the bands looking for DX is a pain. Weighted, larger knobs (about 2 inches in diameter) with rubberized circumferences are supplied on almost all amateur transceivers and shortwave receivers, and for good reason: You can use two or three fingers to keep the knob turning without fatiguing your wrist. If you don't tend to do a lot of tuning, the R8's diminutive knob may not be a disadvantage.

I found the R8's 1.8-kHz selectivity useful for copying weak SSB signals. When I wanted the full effect of a booming signal I switched to 2.3-kHz selectivity. The wider (2.3-kHz) selectivity is fine for stronger signals, or in casual operation, when you care what the other operator's audio actually sounds like.

On the shortwave broadcast bands, the R8 really struts its stuff. After a few A/B comparisons with my transceiver I knew that the R8 had it beat. The choice of bandwidths and the smooth **PASSBAND OFFSET** adjustment, coupled with the distortion-reducing synchronous detector, makes shortwave broadcast listening with the R8 a real pleasure.

Owner's Manual

Between stints at ARRL Headquarters I worked for 12 years as a technical writer. I've been known to read an owner's manual *before* the roast beef caught fire or the plates on the 3-500Zs melted down. The R8 *Owner's Manual* is well done. It was written for nontechnical people, but it doesn't talk down to them. Except for the lack of a schematic diagram, you tech types won't be offended. Read the manual before you start playing with the receiver; you won't be wasting time.

What impresses me most about the R8 manual is its use of graphics. Drake's foray into consumer electronics certainly taught them how to produce superb manuals. The radio's serial interface is clearly explained; I would have enjoyed using it. Drake: Where's the software? Manual space is also provided to log the contents of the receiver's 100 memories.

Lasting Impressions

If I had more time to spend listening to shortwave broadcasts, I'd like to do it with an R8. I like the way it sounds. I usually know the frequency I want to listen to, so I can just punch it in from the keypad. Once I have the station tuned in, I press the **SYNCHRO** button, then sit back and enjoy the program.

Although its operation is somewhat cumbersome, this receiver is considerably less expensive than similar receivers built overseas. (Yes, the R8 is built in the United States!) The S meter has a real mechanical pointer, rather than the solid-state and fluorescent S meters found on many other receivers.

The R8 can be powered from its internal supply (108-264 V ac, selectable on the back panel). You can also power it from 11-16 V dc. This is convenient for portable operation.

Most modern radios, including the R8, provide scanning modes. The R8 can scan all or selected banks of its 100 memories or between the two VFO frequencies. You can choose between immediate or delayed scan resumption. The R8 won't scan with the squelch open, but the manual includes useful tips on setting the squelch and RF-gain controls for efficient scanning. For me, the scanning modes will be more useful when Drake produces a VHF/UHF converter for the R8 (as promised in the manual).

Accompanying tables show performance of our R8, as measured in the ARRL Lab. A receiver, however, must be more than the sum of its specifications. Any receiver that's cranky or cumbersome to use—no matter how well it performs electrically—falls short of providing all the enjoyment we want from our hobby. I'd rather Drake had designed the R8 so the bandwidth and mode selections could be done by pressing one button one time, even if they had to charge more for the receiver as a result. But inexperienced receiver users might find making so many decisions (bandwidth? mode?) as stressful as I found using the R8 *without* these features. If you enjoy listening to shortwave broadcasts and appreciate synchronous detection, 100 memories, a timer and passband offset, you'd do well to consider the R8. It's a good value. If your interests lie more in the ham bands, however, you'll find that the operational shortcomings of the R8 are significant relative to some of the alternatives.

Thanks to Dave Newkirk, WJ1Z, for his contributions to this review.

Manufacturer/distributor: R. L. Drake Company, PO Box 3006, Miamisburg, OH 45342, tel 513-866-2421. Price, $899 plus $10 shipping and handling (Ohio residents must include sales tax).

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