2014

HF Transceiver Survey

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As with most major purchases, there is a wide range of choices among transceivers, ranging from the most basic functionality to more bells and whistles than most operators will ever use. As might be expected, advanced features and performance generally go hand-in-hand with advanced prices.

This section considers "all-band" transceivers with 100 W or more output. Although we call them "HF" transceivers, all cover 160 meters (which is a medium frequency — MF — band). Many also cover a VHF band — 6 meters — while some include 2 meters, and a few feature 70 cm and even higher frequency bands. Such wide frequency coverage is a plus for the Technician class operators who start out on 10 meters and above, but may upgrade in the future, or for anyone who wants to explore those bands without resorting to multiple radios. All radios discussed here include a general coverage receiver that tunes at least from the AM broadcast band to 30 MHz, so they can also be used for entertainment or shortwave listening as well.

The information presented here is current as of mid-2013, but both products and prices can change dynamically in such a competitive marketplace. Check dealer and manufacturer web pages, *QST* ads and Product Reviews as you get close to making a choice.

There are also some nice transceivers available as kits, as well as some that operate at lower power levels. While any of these can provide lots of fun, a new operator may not be ready for the challenge of low power operation or serious kit building.

Categories

Transceivers tend to be grouped into a number of categories based on price points and physical configuration. The price is the typical "street price" — the price they sell for at dealers — not the "list price." Prices are approximate, as of mid-2013, and subject to change (up or down). The categories break down as follows:

Entry-level — Desktop transceivers that cost from around $500 to $1000. They offer features and performance that cost much more only a few years ago.

Mid-range — Desktop transceivers that cost from around $1000 to $2000.

Upper mid-range — Desktop transceivers that cost from around $2000 to $4000.

Top drawer — Transceivers costing $4000 and up.

Portable and Mobile — Radios that straddle the entry to mid-range prices, but are specifically designed for portable and mobile operation.

Unless otherwise noted, the 100 W radios described are designed to operate from a nominal 13.8 V dc power supply, usually at around 20 to 22 A. The radios at higher power levels tend to have special power supply configurations, often requiring operation from ac mains. Most manufacturers offer a 13.8 V "matching" power supply for the 100 W radios. Aftermarket general purpose power supplies meeting the radio's specifications may also be used.

One of the most active areas of transceiver development is in the application of digital signal processing (DSP) and software-defined radios (SDR). These technologies are given their own chapter of the *ARRL Handbook* for that reason, as well as a long sidebar on the subject in the **Receivers** chapter. It is worth continuing to educate yourself on these technologies, as they are displacing a significant number of analog technologies.

Obviously, the assignment of a transceiver to a particular class is somewhat arbitrary and depends on personal tastes and operating requirements. Take the following lists as general assessments and don't be afraid to make your own rankings! In addition, new models and features are introduced continuously. Watch for products announced or reviewed in *QST* and on the manufacturer and dealer websites.

Features of Current Transceivers

Current 100 W (or higher) transceivers tend to include the following features. Some features tend to appear in transceivers of different price ranges, thus the features have been placed in generic groups based generally on price class.

BASIC FEATURES

Even the lowest price entry-level transceivers of every generation have features never even considered in earlier higher-end units. The following is not an exhaustive list but should provide an indication of the benefits of some of the more popular features.

• A general coverage receiver — Typical coverage is from below the medium-wave broadcast band (sometimes with reduced sensitivity) to the top of HF, sometimes well into VHF, depending on transceiver frequency coverage. While this is useful to allow listening to international broadcast stations or other services, it may be even more useful as an adjunct to an amateur's workbench as a test instrument.

• Wide transmit frequency coverage — All current models extend downward to MF (160 meters) and most extend into VHF with coverage through 6 meters. Some go further

into VHF and even UHF. In some cases the additional coverage may obviate the need for one or more additional radios in the station, making for a more compact, and sometimes less expensive, station.

• Multiple modes of operation — Most current transceivers offer SSB, CW, AM and FM modulation and detection. Most offer provision for digital modes. Depending on frequency coverage, some "HF+" transceivers can also serve as VHF FM transceivers, offering standard repeater frequency offsets, squelch and tone encoding.

• Choices of selectivity — All current generation transceivers offer DSP-based variable selectivity. In lower-cost models it tends to be a small but adequate number of discrete choices, while in higher priced units selectivity is often continuously variable in 50 or 100 Hz steps. Advanced units allow shaping of the passband as well as high- and low-frequency rolloff adjustment. Some offer a dual-passband filter, designed to separately pass each tone of an FSK signal and not the frequencies between them.

• Dual VFO operation — All current designs offer instant selection of either of two operating frequencies to allow split-frequency operation. This allows the setting of one frequency for transmit and another for receive. A single switch or button can be used to toggle between the two so that the transmit frequency can be monitored before transmitting.

• DSP impulse noise and carrier reduction — Most DSP-equipped transceivers provide for the reduction of impulse noise such as that from ignition systems or appliances.

• CW keyer — Most current model transceivers include the capability to connect keyer paddles for sending CW via an internal keyer. Some also include memories to allow one-button transmission of short messages.

• Removable front panel — Transceivers designed for mobile operation often have a removable front panel. This allows a compact control head to be mounted near the operator, while the radio's main chassis can be located in the trunk or other out-of-the-way spot.

FEATURES FOUND IN ADVANCED TRANSCEIVERS

More advanced transceivers tend to have additional features for their increased price. Most are larger than the basic units so that the front panels can accommodate additional controls and displays to support the extra features.

• Multiple roofing filter bandwidth — Most basic transceivers incorporate a single roofing filter with sufficient width to permit use on all modes. A typical value is 15 to 20 kHz. Improved close-in dynamic range performance can be obtained by having narrower roofing filters for narrow bandwidth modes as described in the **Receivers** chapter.

• Adjustable noise blanking — Some transceivers include a separate wideband receive channel designed to detect and blank the main receiver in the presence of impulse noise. This capability is often independent of the similar DSP-based function. One or the other may be found to be better at eliminating noise from particular sources, while sometimes using both is even more helpful. Some transceivers offer two separate methods of noise blanking, each suited for different common types of impulse noise.

• Choices of AGC parameters — Most transceivers provide automatic AGC settings for different operating modes. Some advanced transceivers provide additional choices to allow optimization for different kinds of operation and different ambient noise levels. For example, to maximize sensitivity for weak signals, the AGC operating threshold should generally be set above the external noise level. This will vary depending on ionospheric conditions. Other parameters include the slope of the AGC curve and hold and attack times.

• Frequency memories — Advanced (and some basic) transceivers include the capability to store operating frequencies and other settings in memory. "Band-stacking registers" are multiple memories for each band that are typically accessed by pressing the band selection button multiple times. Typically they will store two or three frequencies per band, along with mode, filter and other settings, in a last-in, first-out register stack.

• Dual receive — Some higher-end transceivers include two independent receive channels. Dual receive channels can be useful to monitor two frequencies simultaneously. For example, you could listen simultaneously to transmit and receive frequencies being used by a DX station operating in split mode.

There are some subtle differences between the *sub-receiver* capabilities of different model transceivers. In some transceivers, the sub-receiver can only be used in the same band as the main receiver. This is not a limitation for normal split operation, but it does not permit monitoring a different band for openings or other activity. While some transceivers offer a duplicate receiver system for the sub-receiver, others have sub-receivers with lower dynamic range performance or fewer filter options than the main receiver.

Some sub-receivers have independent antenna input connections that allow operation with two different antennas. If the tuning of the two receivers can be locked together, that can provide a kind of diversity operation to reduce fading. Typically that might entail polarization diversity (one horizontal antenna, one vertical); space diversity with two antennas separated by a wavelength or so; or arrival angle diversity, using antennas at different heights.

• Panadapter — While a visual view of the received spectrum has been possible for decades with a station accessory called a *panadapter, band scope, spectrum analyzer* or other trade name, these devices were not too common in amateur stations until manufacturers started building display screens into transceivers. Many current transceivers offer panadapters in different forms. Often they offer views of signals on a band, adjustable over a range from the immediate vicinity of the operating frequency to the whole band. Some transceivers with dual receivers provide either dual panadapters or the ability to use one on the second receiver to keep track of band openings while communicating on the main band. In some cases, the receive circuitry is shared with the panadapter so that the audio is disabled during the time of the scan.

A *real-time* panadapter scans the frequency segment and repeats the scan over and over, giving an appearance of continuous updates. Thus newly arrived signals will show up during each scan. Some panadapters offer a single-pass or *one-shot* functionality in which a button press initiates a single scan over the selected range. The display retains the same snapshot of band activity until the next time the button is depressed. While this can provide a sample of band activity, it does not provide the same level of information as a real-time display.

Some transceivers provide a wideband IF output ahead of roofing filters so that an external panadapter can be used to monitor the received band. The wideband IF output can be used by other external signal processing equipment as well.

• Higher power — Transceivers are available at many power levels, from the very compact and portable low power (QRP) transceivers to medium power output sets. While the usual 100 W PEP output transceivers are the most popular, some transceivers provide 200 W PEP output or more.

• AF equalization — Long a capability of amateurs interested in broadcast-quality voice signals, newer transceivers provide a DSP-based audio equalization capability similar to professional studio control consoles. This is often available in both transmit and receive. In receive mode, it functions largely as a higher resolution tone control. In transmit mode, equalization can be used to

shape audio response to provide higher fidelity. Or it can be used to focus the response to best punch through a DX pileup or compensate for individual voice or microphone response.

• Memory voice recorder — Sometimes called a *voice keyer* because of the similarity to a CW memory keyer, this function allows you to record and play back short messages. Voice keyers use digital technology and store the voice signal into memory. Different radios have different numbers of such memories, and some also can record received audio for playback on the air or to record a contact.

• RTTY and PSK31 decode — Some transceivers, generally at the upper end of the price spectrum, include the capability to decode RTTY and PSK31 transmissions on the display screen, eliminating the need for a separate PC and sound card. There usually is a limited amount of screen space for decoded messages, but it is usually plenty for contest exchanges or occasional contacts. A few transceivers provide connections for a computer keyboard to allow sending without an attached PC.

Entry Level Transceivers

As of mid-2013, there are seven radios in full production that fall in or near this category, the Alinco DX-SR8T, ICOM IC-718 and IC-7200, the Kenwood TS-480SAT and the Yaesu FT-450, FT-857D and the FT-897D. The IC-7200, Kenwood TS-480SAT, Yaesu FT-857D and FT-897D are marketed as portable units, so they are also shown in that category. Radios in the portable and mobile category that fall in this price range may be worth checking out, even if you plan on operating from home.

The Alinco DX-SR8T, shown in **Fig 1**, is available at the lowest price of any new 100 W HF radio in any category, about $530 at this writing. It is a very basic radio in terms of its capabilities and options. The DX-SR8T operates on the 160 through 10 meter bands, including the 60 meter channels as defined at its introduction (there have been some changes since). Modes supported are SSB, CW, AM and FM with fixed IF bandwidths for each mode including a narrow CW filter. While advertised as a "desktop" transceiver, it does have a removable faceplate, making it worth considering for mobile operation as well.

The IC-718, shown in **Fig 2**, was the lowest price entry for some years and is still available but at a somewhat higher price — about $700 at this writing. The IC-718 has been around for a while so it doesn't have all the latest digital technology or cover 60 or 6 meters. This radio was produced before IF DSP was common throughout the industry, but it does include an audio DSP add-on module that offers digital noise reduction and a digital notch filter and is provided as standard equipment.

The operating bandwidth is set via discrete physical filters. A 6 kHz filter for AM and a 2.4 kHz filter for SSB are provided. A single additional slot is provided for an optional 500 Hz CW bandwidth filter, or for a 1.9 kHz bandwidth SSB filter. While they can be installed later, the filters do need to be soldered to the PC board, a bit of a tricky operation even for an old timer, so if you want one, you might want to have it installed by your dealer. Aftermarket filters are also available.

Fig 1 — The Alinco DX-SR8T desktop HF transceiver. While marketed as a desktop unit, its removable front panel makes it suitable for mobile operation as well.

Fig 2 — The ICOM IC-718 desktop HF transceiver.

Fig 3 — The Yaesu FT-450D desktop HF and 6 meter transceiver.

Fig 4 — The Yaesu FT-897D, an entry level transceiver with a portable orientation and coverage up to 70 cm.

Fig 5 — The ICOM IC-7200 desktop HF and 6 meter transceiver — similar in size to the IC-718, but with an outdoor focus.

The IC-718 does not include an antenna tuner, but provision is made for one of two ICOM external tuners — the AT-180 for coax fed antennas with an SWR of 3:1 or less, or the AH-4 for wire antennas. Aftermarket tuners are also available from a number of manufacturers.

The IC-718 is generally easy to operate and includes all the basic controls and capabilities to get you on the air on HF. If you need to add features through available options, the price will go up considerably, bringing it more in line with some of the other choices.

The Yaesu FT-450D, shown in **Fig 3**, is an updated version of the FT-450 with more digital processing features. The FT-450D includes the 60 meter channels and 6 meters. It also provides for FM in addition to SSB, AM, CW and data operation. It is very much like its bigger and more expensive siblings in that it built around a common DSP architecture that provides multiple operating bandwidths to cover each mode. There are three fixed bandwidth choices each for CW, SSB and AM. These are all built in without having to buy options. An internal antenna tuner is included with the base FT-450D.

The Yaesu FT-897D (see **Fig 4**) and ICOM IC-7200 (see **Fig 5**) are in a way opposites to the previous transceivers of their same brands. That is, the IC-7200 is a modern, DSP based, radio sharing some features of the current crop of ICOM radios but packaged in many ways similar to the IC-718. The FT-897D, on the other hand, is of the same generation as the IC-718, in that it uses analog IF filters and provides audio-based DSP.

Both transceivers are marketed as portable units, with the IC-7200 emphasizing physical ruggedness. The FT-897D offers a number of options for portable use including a rechargeable internal battery pack that can make the transceiver self-contained as a low-powered transceiver. VHF and UHF operation are provided with the '897D.

The Kenwood TS-480SAT is discussed in the following section, along with its somewhat higher priced 200 W sibling, the TS-480HX that trades the additional power for the internal tuner.

Portable and Mobile Transceivers

There are many choices in this category. These are 100 W (or more) HF transceivers that usually include one or more VHF/UHF bands. They have many of the features of larger radios, but they are compact and designed for the tight cockpit of modern vehicles, or for easy transportation to a portable location.

There is no reason these radios can't be operated from a home station as well. The usual trade-off is that they have smaller front panels with fewer and smaller controls. They often make up for the missing controls with more programmable *menus* that some operators may find restricting. Still, they may be perfect for a compact home radio station, and they can be moved to a vehicle as well.

There are too many radios in this category to discuss separately, so we'll highlight some of the differences in **Table 1**. Note that all, except for the portable or field oriented FT-897D and ICOM IC-7200, have a removable front panel that is designed to be mounted in the front of a vehicle while the body of the radio can be mounted in an out-of-the-way spot. All can be combined together in some way to operate as a single unit for home or field use. Perhaps notable in this group, the Kenwood TS-480 (**Fig 6**) offers a choice of models with either an internal antenna tuner or a 200 W output transmitter, the only one in this price category. The Kenwood TS-B2000 is a version of the TS-2000 that incorporates a separate front panel.

Some of these radios can operate into the VHF and UHF range. Not only do they operate FM there, but they can also operate SSB, CW and even AM, making them much more versatile than the usual VHF FM-only mobile setup. Some will even allow reception of wideband FM broadcast signals, but none will likely be confused with a high fidelity audio system.

Table 1
Transceivers in the Entry and Portable/Mobile Categories
All are 100 W transceivers except as noted.

Model	*Street Price*	*DSP*	*60 Meters*	*V/UHF*	*Ant Tuner*
Entry Level					
Alinco DX-SR8T	$530	No	Yes	No	No
ICOM IC-718*	$700	NB, NF	No	No	No
ICOM IC-7200*	$1000	IF	Yes	6 Meters	No
Kenwood TS-480SAT	$930	AF	Yes	6 Meters	Yes
Yaesu FT-450D*	$950	IF	Yes	6 Meters	Yes
Yaesu FT-857D	$850	AF	Yes	6, 2 m; 70 cm	No
Yaesu FT-897D*	$970	AF	Yes	6, 2 m; 70 cm	No
Portable/Mobile					
ICOM IC-7000	$1200	IF	Yes	6, 2 m; 70 cm	No
ICOM IC-7200*	$1000	IF	Yes	6 Meters	No
Kenwood TS-480SAT	$930	AF	Yes	6 Meters	Yes
Kenwood TS-480HX**	$1060	AF	Yes	6 Meters	No
Kenwood TS-B2000***	$1400	IF	Yes	6, 2 m; 70 cm	Yes
Yaesu FT-857D	$850	AF	Yes	6, 2 m; 70 cm	No
Yaesu FT-897D*	$970	AF	Yes	6, 2 m; 70 cm	No

*Single unit radio, others have separable control head.
**200 W output; requires one 40 A, or two 20 A power supplies.
***Includes second receiver for AM or FM reception.

Fig 6 — Kenwood TS-480HX, the only transceiver in this category with a 200 W transmitter. The TS-480SAT looks similar, but offers 100 W output and an internal antenna tuner.

Mid-Range Transceivers

What do you get if you dig a bit deeper into the checkbook? Generally, you get a somewhat larger radio with easier to grasp controls, more features — or more choices within a feature type, such as more operating bandwidths to choose from. All are relatively recent designs with IF DSP, allowing a wide range of operating bandwidths.

You also may get better receiver performance — perhaps one of the key elements that separate the radios at the higher price ranges. In this case we are talking about the ability to receive a weak signal within a kHz or two of a strong one — *close-in dynamic range*. The higher the number the better, and as noted there is quite a range. While this is only one of the many parameters evaluated in the ARRL Lab for product reviews, some believe it is the key in a crowded operating environment such as contesting or DX chasing. When the band is crowded with very strong signals operating nearby, you can experience interference *generated in your receiver* caused by mixing products from those nearby signals. The higher the close-in dynamic range, the less likely you are to experience internally generated interference to stations you are trying to hear. (Interference from IMD products is discussed in the **Receivers** chapter and in the **Test Equipment and Measurements** chapter.)

The Elecraft K3 (**Fig 7**) provides excellent performance in this category in any price range, and shows up in almost all ranges because of its configuration flexibility. Also in this group is the FlexRadio FLEX-3000 (**Fig 8**) software-defined radio. This transceiver is in a compact enclosure that makes it a good match for a laptop PC. The FLEX-3000 offers excellent receiver performance and the epitome of flexibility. Although it doesn't have the space for a second receiver or antenna options of higher-end FlexRadio models, it will look the same on the PC screen and likely sound the same to the far end.

We have summarized some of the key features and parameters in **Table 2**. Some of the equipment needs a bit of additional explanation. Note that none of the radios in Table 1 include a fully-capable second HF receiver, but the TS-2000 (**Fig 9**) does have a second receiver mainly for VHF FM use — perhaps handy for some who wish to monitor their local repeater while operating

Fig 7 — Elecraft K3 HF and 6 meter transceiver. The flexibility of selectable options for this top performing radio gets it listed in three price categories.

Fig 8 — FlexRadio FLEX-3000 software-defined radio. This radio operates with *PowerSDR* software and provides excellent performance in a small box.

Table 2
Transceivers in the Middle Range Category
All are 100 W transceivers.

Model	*Street Price*	*DSP*	*60 Meters*	*V/UHF*	*Ant Tuner*	*IMD DR (2 kHz)*
Elecraft K3/100F	$2350*	IF	Yes	6 Meters	$350	103 dB
FlexRadio FLEX-1500	$650	IF, AF	Yes	6 Meters	No	86 dB
FlexRadio FLEX-3000	$1699	IF	Yes	6 Meters	No	95 dB
ICOM IC-7410	$1600	IF	Yes	6 Meters	Yes	88 dB
Kenwood TS-2000**	$1500	IF	No	6, 2 m; 70 cm	Yes	57 dB
Kenwood TS-2000X**	$1950	IF	No	6, 2 m; 70, 23 cm	Yes	57 dB
Kenwood TS-590S	$1500	IF	Yes	6 Meters	Yes	97 dB***
TEN-TEC Eagle	$1819	IF	Yes	6 Meters	$200	98 dB
Yaesu FT-950	$1450	IF	Yes	6 Meters	Yes	71 dB
Yaesu FTDX1200	$1850	IF	Yes	6 Meters	Yes	83 dB

*Base assembled 100 W unit. IMD measured with optional ($140) 400 Hz roofing filter. Kit version available.
**Includes a second receiver for simultaneous AM or FM reception only.
***Downconverting bands — 160, 80, 40, 20 and 15 meters. IMD DR is 82 dB on the upconverting bands — 30, 17, 12, 10 and 6 meters — as well as general coverage.

Fig 9 — Kenwood TS-2000. This transceiver operates on MF, HF, VHF, UHF, and the 1.2 GHz band as an option, providing broad frequency coverage in a single package.

Fig 10 — The Kenwood TS-590S offers a high performance receiver on the primary HF amateur bands and many digital features.

Fig 11 — The ICOM IC-7410 covers HF and 6 meters with good receiver performance in a compact package.

Mid-Range Transceivers (continued)

HF. In the upper middle range some do have independent second receivers so that you can listen to signals on two frequencies — one in each ear, if you wish — handy while operating on split frequencies and a popular option with DX chasers.

The Kenwood TS-590S (see **Fig 10**) offers a high performance downconverting receive capability on the most popular amateur HF bands (160, 80, 40, 20 and 15 meters) and offers many digital features in a compact en-

Mid-Range Transceivers (continued)

velope. There is a separate receiver that uses upconversion for the 60, 30, 17, 12, 10 and 6 meters as well as for general coverage receive.

Other popular radios in this category include the ICOM IC-7410 (**Fig 11**), TEN-TEC Eagle (**Fig 12**) and the Yaesu FT-950. As this was written Yaesu introduced the FTDX1200 (**Fig 13**), which fits in this category and includes a colorful display screen.

Fig 12 — The TEN-TEC Eagle, a compact HF and 6 meter transceiver provides excellent receive performance on all amateur bands.

Fig 13 — The Yaesu FTDX1200 covers 160 through 6 meters and offers a colorful screen and spectrum display.

Upper Mid-Range Transceivers

Transceivers in the upper mid-range group offer a number of choices of different desirable features. Key parameters are noted in **Table 3**. Some offer more or different features, while others make a push toward higher performance. At the top of the next bracket, manufacturers try to provide everything, while here you need to look carefully and decide what is most important.

The TEN-TEC Omni VII (**Fig 14**) provides very good receiver dynamic performance along with a general coverage receiver and a single-scan panadapter display. The ICOM IC-9100 (**Fig 15**) has the capability to serve as both an MF/HF transceiver as well as a multimode VHF/UHF radio with an option for the 1.2 GHz band.

The FTDX3000 (see **Fig 16**) is a lower priced, 100 W, single receiver version of "top drawer" FTDX5000. The FlexRadio 5000A (**Fig 17**) is a software-defined radio that re-

Table 3
Transceivers in the Upper Middle Range Category

All are 100 W transceivers. All have IF DSP and 60 meter coverage.

Model	*Street Price*	*2nd Rcvr*	*V/UHF*	*Ant Tuner*	*IMD DR (2 kHz)*
Elecraft K3/100F	$2910*	Yes	6 Meters	$350	103 dB
FlexRadio FLEX-5000A	$2799**	$699	6 Meters	$299	99 dB
ICOM IC-7600	$3450	DW***	6 Meters	Yes	88 dB
ICOM IC-9100	$2950	No	6, 2, 70 cm†	Yes	87 dB
TEN-TEC Omni VII	$2795	No	6 Meters	$300	82 dB
Yaesu FTDX3000	$2400	No	6 Meters	Yes	104 dB

*Assembled with dual receiver with 2700 Hz roofing filter in each receiver. IMD measured with optional 400 Hz roofing filter ($140).
**Requires a PC for operation. Discontinued mid-2013 with 6000 series introduction.
***Dual watch — combines reception of two signals in same band into same audio channel.
†23 cm available as an option.

Fig 14 — The TEN-TEC Omni VII offers very good receiver performance and a single-pass panadapter.

Fig 15 — The ICOM IC-9100H transceiver offers coverage of 1.8 through 440 MHz with an option for 1.2 GHz operation.

Upper Mid-Range Transceivers (continued)

quires a separate PC and software to operate it. As this was written, FlexRadio was introducing the 6000 series SDRs and phasing out the 5000 series.

The ICOM IC-7600 (**Fig 18**) fills the slot of the previously available and popular IC-756PROIII, but offers additional dynamic performance due to a choice of 3, 6 and 15 kHz roofing filters, supporting all modes.

The Elecraft K3 shows up in both middle categories and in the top drawer as well, since it is modular in design and can be purchased in different configurations. There are many more options which some may find desirable, but the listed prices are for a fully assembled, basic 100 W transceiver in Table 1 with a single receiver and in Table 2 with a dual receiver. The K3 is also offered in kit form at significant savings.

Fig 16 — The Yaesu FTDX3000 offers the high performance receiver capability of the FTDX5000 in a more economical 100 W, single receiver configuration.

Fig 17 — The FlexRadio 5000A, a software-defined radio that provides excellent performance, flexibility and growth potential through its computer control capability and optional second receiver and tuner. This radio was discontinued in mid-2013 with the introduction of the FlexRadio 6000 series.

Fig 18 — The ICOM IC-7600 transceiver provides improved receiver performance through included 3, 6 and 15 kHz roofing filters.

Top Drawer Transceivers

Transceivers at the very top of the price range are available from a number of manufacturers. These transceivers span a considerable variation of prices, but from $4000 and up it probably doesn't make too much sense to subdivide the list. Buying decisions are driven by subtle differences in features or the desire for optimum receiver performance, a key issue with many contest and DX-focused operators.

Among many families of transceivers, there is some flexibility here in terms of hardware. The previously discussed Elecraft K3 epitomizes flexibility through its extensive options list, as well as top-shelf receiver performance. It is definitely a radio that can grow with the operator's needs! Yaesu offers two families of radio systems in this group. The Yaesu FTDX5000 (**Fig 19**) offers exceptional receiver near-in dynamic range measured in the ARRL Lab. As this was written, the FTDX5000MP was the only version available, and it includes the SM-5000 station monitor, a more precise master oscillator and 300 Hz roofing filter as well as a 200 W PEP transmitter. The FTDX9000D also transmits at the 200 W level, while the FTDX9000MP offers 400 W PEP on transmit. At ICOM's top end, the IC-7700 is basically a top of the line IC-7800 (**Fig 20**) without a second receiver — not something that is needed for every application.

Available, but not yet run through the *QST* Product Review process as we write this, are a completely new transceiver from Kenwood, the TS-990S (**Fig 21**); a new family of modular software defined transceivers from FlexRadio, the FLEX-6000 Signature series with "Smart SDR;" and a reintroduction of the Hilberling PT-8000A transceiver. All are in this price category.

Fig 19 — The Yaesu FTDX5000MP is a top-performing 200 W transceiver, featuring a 300 Hz roofing filter and the companion SM-5000 station monitor.

Fig 20 — The ICOM IC-7800 provides excellent performance and an extra flexible display system.

Fig 21 —The TS-990S is Kenwood's entry into the top-drawer category. If offers two receivers with high dynamic range, a 200 W transmitter and a host of interesting features.

Table 4
Transceivers in the Top Drawer Category

All have IF DSP and 60 meter coverage.

Model	*Street Price*	*2nd Rcvr*	*Power*	*V/UHF*	*Ant Tuner*	*IMD DR (2 kHz)*
Elecraft K3/100F*	$5000*	Yes	100 W	6 Meters	Yes	103 dB
ICOM IC-7700	$7200	No	200 W	6 Meters	Yes	87 dB
ICOM IC-7800	$10,500	Yes	200 W	6 Meters	Yes	86 dB
Kenwood TS-990S	$8000	Yes	200 W	6 Meters	Yes	101 dB
Yaesu FTDX5000MP	$6000	Yes	200 W	6 Meters	Yes	103 dB
Yaesu FTDX9000D	$10,500	Yes	200 W	6 Meters	Yes	87 dB
Yaesu FTDX9000MP	$11,800	Yes	400 W	6 Meters	Yes	85 dB

*Assembled; price can vary greatly with internal and external options. See Elecraft website for a full list of options and prices.

Software Defined Radios

We described some HF transceiver choices as "software-defined radios" or SDR. It may be worth a short digression to discuss this topic in the context of available equipment. Software-defined radio architecture and design is covered in more detail in the **DSP and Software Radio Design** chapter.

As we'll discuss, there are a range of definitions — subject to some controversy — on what constitutes an SDR in the Amateur Radio world. The FCC has defined the SDR concept in terms of their commercial certification process as:

"…a radio that includes a transmitter in which the operating parameters of the transmitter, including the frequency range, modulation type or conducted output power can be altered by making a change in software without making any hardware changes."

The FCC expects this to yield streamlined equipment authorization procedures by allowing "manufacturers to develop reconfigurable transceivers that can be multi-service, multi-standard, multi-mode and multi-band…." (From FCC Report and Order 01-264, released Sep 14, 2001.) In this context, they are envisioning radios that can be modified at the factory by using different software to meet different requirements. While they allow for field changes, the FCC's focus is different than ours.

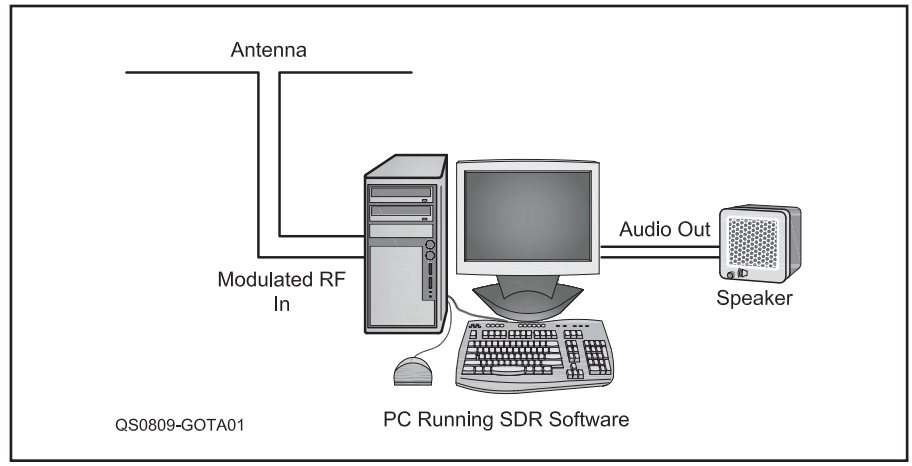

Fig 22 — Conceptual block diagram of an ideal software-defined radio (SDR) receiver.

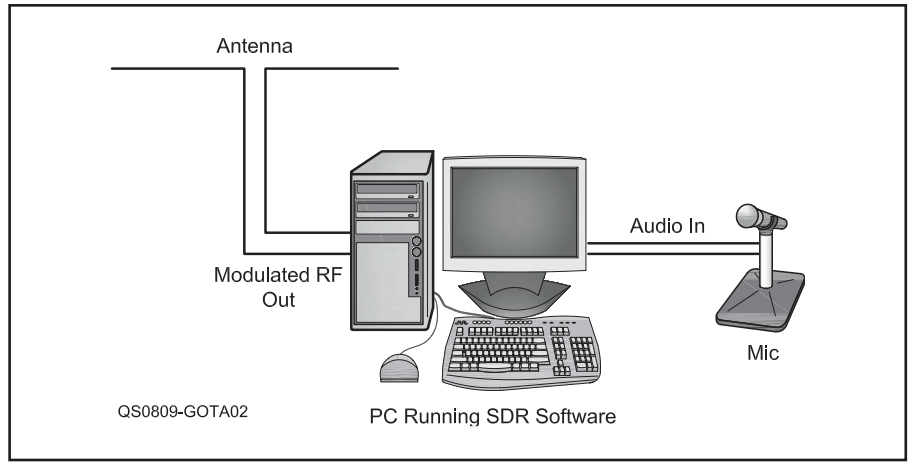

Fig 23 — Conceptual block diagram of the transmit side of an ideal SDR transceiver.

SDR IN THE AMATEUR WORLD

In the amateur environment, we are particularly interested in radios that can be changed through software by the end user or operator to meet their needs or to take advantages of newly developed capabilities.

The ideal SDR would thus have a minimum of physical constraints. On the receive side, the antenna would be connected to an analog-to-digital converter that would sample the entire radio spectrum. The digitized signal would enter a processor that could be programmed to analyze and decode any form of modulation or encoding and present the result as sights and sounds on the output side of the processor.

On the transmit side, the processor would accept any form of information content, convert to digital if needed, process it into a waveform for transmission and send out a complex waveform conveying the information as an RF signal on the appropriate frequency or frequencies, at the desired power level to transmit from the antenna.

Not surprisingly, our utopian SDR is much easier to imagine than to construct. As a practical matter, our usual PC has some constraints that don't allow us to do quite what we want. Still, for a few hundred dollars, it is possible to purchase a PC that gets us fairly close.

The key to amateur SDR operation with a PC is the analog to digital conversion process. This is the point at which the analog RF signals are digitized for processing. Early and more basic SDRs made use of a computer's sound card, or sometimes an external interface device, to perform this function. The usual computer sound card is usually the limiting point in terms of performance, as described below. Advanced SDRs, such as some of those from FlexRadio, have the processing functionality built in and are thus able to take advantage of higher performance digital to analog processing engines that can sample faster, allowing the direct processing of higher frequencies. They also can provide a higher dynamic range.

The software will determine the type of processing and the nature of the signals we can deal with. It can also take the results of processing and convert them into an analog signal. This sounds like just what we are looking for to make an SDR — and it is. Such an SDR in receive mode would consist of the blocks in **Fig 22**. We do have a few significant limitations:

- For most sound cards the sampling rate is 192 kHz or less, limiting the received analog signal to a frequency of 96 kHz. Some kinds of dual channel processing allow a response as high as the sampling rate. (Sampling rate limitations, also referred to as Nyquist rate, require sampling the incoming signal at twice the highest frequency in the sampled signal.)
- Most sound cards do not have the sensitivity required in a radio receiver and on the transmit side (see **Fig 23**) can only output 100 mW or less.

Thus we are faced with the need to insert some external processing functions outside the PC. These will be used, at a minimum, to translate the frequency range we wish to

use to one that the sound card can deal with on the receive side. On the transmit side, we will need to translate the frequency range up to the desired portion of the radio spectrum and increase the signal to our desired transmit power level.

The SDR designer, as with all designers, is faced with a trade off. The equipment external to the PC required to make it do what we want may also limit the choices we can make by software change in the PC. The more hardware features we build in, the fewer choices we may have. In addition to PC software, there is often firmware, hard wired instructions in the box outside the PC. This has resulted in two general approaches in SDR.

The "Blank Front Panel" Architecture

Radios marketed as SDRs tend to be of this type. The classic is the FlexRadio FLEX-5000A, reviewed in *QST* for July 2008 and now discontinued as the 6000 series is introduced. The front panel has no controls and all control functions are implemented by soft buttons on the *PowerSDR* software's computer screen (**Fig 24**), or via pointing and knob devices that connect to the computer. The FlexRadio FLEX-1500 is the 5 W entry in the FlexRadio product line, intended for QRP and transverter use.

There are a number of similarly configured radios useable with the same open source *PowerSDR* software freely available from FlexRadio under the GNU Public License. (Source code for software called "open source" can be viewed and modified. Thus, not only can you upgrade the radio, but also change functionality to make the radio do what you want.)

The "Looks Like a Radio" Approach

Many current radios are actually built as SDRs. Some are provided with a mechanism to allow an easy end-user upgrade to new firmware revisions. These radios look like most any other pre-SDR radio in that they have front panels with knobs and dials. Unless you looked at all the revisions to the operating instructions you wouldn't know that they were field-reconfigurable.

Another distinction between the groups is that most of the firmware for the radios in this group is proprietary with revisions available only from the manufacturer, at least as of this writing. That isn't to say that a solid programmer couldn't and perhaps hasn't developed custom software for one of these radios, but it hasn't happened often.

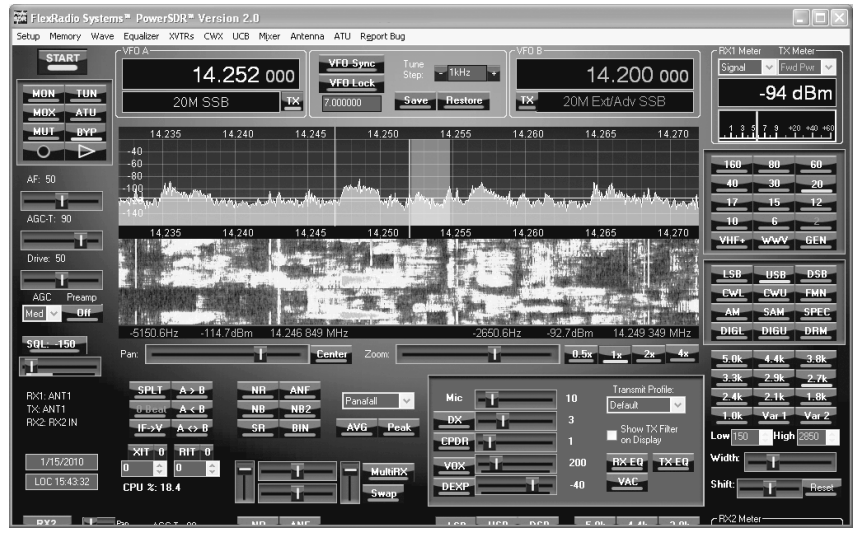

Fig 24 — One version of the main operating screen of PowerSDR operating software.

Differences in Performance

The blank front panel architecture radios generally have the most flexibility in operation, since they are not constrained by the physical buttons and knobs on the front panel. The more traditional-looking versions with physical controls and displays may take advantage of those hardware constraints to gain improved performance at the expense of operating flexibility, but a look at the specs will indicate that it isn't always the case. Some blank front panel SDRs offer top shelf performance.

There will always be some who prefer the more traditional radios and are happy to have it configured and to let it stay the way they like it. Others, especially those who enjoy computers as well as radio, will prefer a transceiver that might get better with the next generation of computers, sound cards, or software. What's really nice is that we can go whichever direction we choose!

Making a Selection

You know the facts — how can you choose? Looking at data tables and product reviews (all *QST* Product Reviews since 1980 are available to ARRL members online at **www.arrl.org/product-review**) provides a great start, but just as with finding the perfect life partner, the numbers don't tell it all. With radios there's also an element of love at first sight, tempered by the way the radio feels to you as you operate it — ergonomics. Each manufacturer has a different philosophy for structuring the controls and menus, and you may find a strong preference for one person-to-machine interface over another.

If you have an opportunity, try out the radios you are thinking of buying. If you are in a local club, find out who uses radios that you are considering and seek an invitation to come over and try them out. Most hams love to show off their stations. Perhaps you have a nearby dealer who has some demo setups, or you can find some at a larger hamfest, or at Field Day. If you're in the northeast, drop by ARRL Headquarters and be a guest operator at W1AW — we have many radios available to try. Nothing beats a test drive!

Transceivers with VHF/UHF Coverage

Transceivers discussed so far include a wide range of features and operational capability. While some transceivers offer capability into the UHF or microwave region, most amateurs start with a transceiver that operates over the MF to HF frequency range, often extending into VHF at 6 meters. It is also true that most amateurs have at least a passing acquaintance with higher VHF bands, perhaps 2 meter or 70 cm FM communications through local repeaters.

At some point, you may have heard enough about satellite communication or VHF/UHF beyond-line-of-sight propagation modes such as troposcatter, sporadic-E, aurora or moonbounce to want to try some of these activities. They take place using SSB, CW and narrow bandwidth digital modes, so a VHF/UHF FM transceiver won't do, although FM satellites are almost as easy to use as the local repeater.

As noted previously, several HF transceivers cover through the VHF bands and some into UHF at 70 cm. Among the entry level and portable/mobile radios, the compact Yaesu FT-857D and FT-897D as well as the ICOM IC-7000 models offer VHF operation on 6 and 2 meters and 70 cm, supporting SSB, CW, AM and FM modes on each band.

Two current full size HF transceivers extend operation well into the VHF and UHF regions as well. The Kenwood TS-2000 and ICOM IC-9100H not only offer all modes of operation from 160 meters to 70 cm, but each also offers an internal option for the 23 cm (1240 to 1300 MHz) microwave amateur band. Each can support FM repeater operation as well as the full duplex modes needed for operation through satellites.

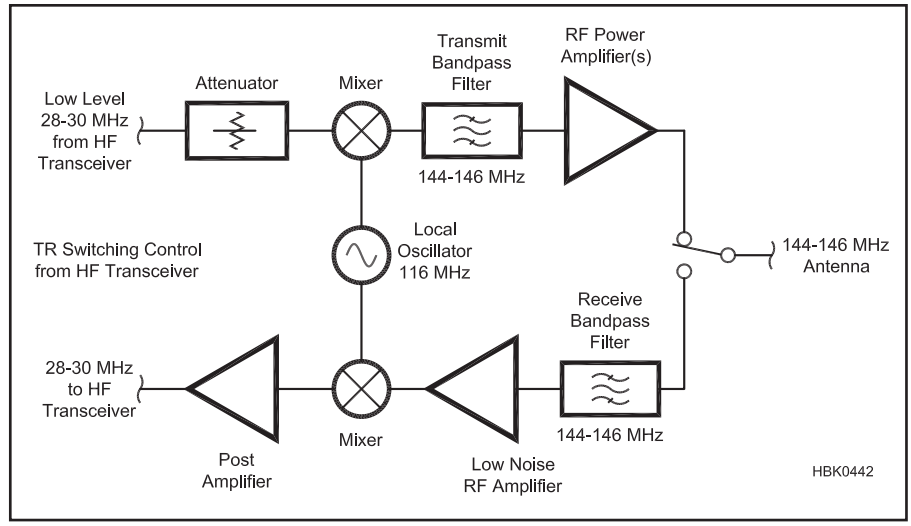

Fig 25 — Block diagram of a basic 2 meter to 10 meter transverter.

Using an HF Transceiver at VHF/UHF

If you have the HF transceiver you want and would like to try the higher VHF and UHF bands, a viable option is a VHF or UHF transverter. A transverter essentially adds an additional conversion stage, along with pre- and post-amplification, to translate receive and transmit frequencies to a new range.

At VHF, UHF and microwave frequencies, transverters that interact with factory-made transceivers in the HF or VHF range are common and are often home-built. These units convert the transceiver transmit signal up to a higher frequency and convert the VHF/UHF receive frequency down to the transceiver receive frequency. The configuration of a 2 meter transverter is shown in **Fig 25**.

For microwave frequencies, it's common for transverters to have a 144 MHz IF for connection to a multimode 2 meter transceiver. Use of a higher IF makes image filtering easier. Sometimes transverters use two stages of conversion — microwave to 2 meters, and then 2 meters to 10 meters for use with an HF transceiver.

The resulting performance and signal quality at the higher frequencies are enhanced by the frequency stability, bandwidth filters and signal processing capabilities of the transceiver. A transverter makes stable SSB and CW operation feasible on bands from 144 through 10 GHz and higher.

TRANSVERTER DESIGN

The methods of individual circuit design for a transverter are not much different than methods that have already been described. The most informative approach would be to study carefully an actual project description.

The interface between the transceiver and transverter requires some careful planning. For example, the transceiver power output must be compatible with the transverter's input requirements. This may require an attenuator (or an amplifier) or some modifications to a particular transverter or transceiver. There is no standard level among transceiver and transverter brands, so check to see that your HF transceiver has a low-level transmitter output. Also important: a dedicated receiver input for transverter use, as well as some provision for TR switching.

The Elecraft K3 is an example of an HF transceiver with well thought out transverter provisions. It has dedicated, separate transverter input and output ports that are available on an optional interface board. In addition, the band switch directly supports transverters just as if they were bands in the transceiver. The frequency display shows the VHF or UHF frequency directly for up to nine transverters. The appropriate IF frequency is set up for each band, typically 10 or 6 meters, but any others also can be used. An offset is applied to the frequency calibration to compensate for any error in the local oscillator frequency of the selected transverter and a control signal is sent to select the transverter depending on band selected.

The receive converter gain must not be so large that the transceiver front-end is overdriven, causing intermodulation and blocking. On the other hand, the transverter gain must be high enough and its noise figure low enough so that the overall system noise figure is within a dB or so of the transverter's own noise figure. The formulas in the **Receivers** chapter for cascaded noise figure should be used during the design process to assure good system performance. The transceiver's performance should be either known or measured to assist in this effort.

AVAILABLE TRANSVERTERS

If building a transverter from scratch is not for you, a number of manufacturers produce assembled or kit transverters for the VHF through microwave bands. Transverters that have been reviewed in *QST* include the following, with key ARRL Lab results summarized in **Table 5**:

Down East Microwave makes transverters from 6 meters to 3 cm. The ARRL reviewed

their 144-28HP 2 meter transverter in *QST*, see **Fig 26**. A similar transverter for 222 MHz, the 222-28, was also reviewed.

Elecraft makes transverter kits from 6 meters to 70 cm including 1.25 meters. The ARRL reviewed their XV144 2 meter transverter kit in *QST* (see **Fig 27**). They also offer a 2 meter transverter, the K144XV, that is designed to fit within the K3. With the addition of the K144XV, the K3 covers 160 through 2 meters from a single compact box. The portable and trail oriented KX3, reviewed in December 2012 *QST* has provision for an internal 2 meter transverter that had not been released when this was written.

Kuhne Electronics (DB6NT) makes transverters from 2 meters to 3 cm, except for 1.25 meters. The ARRL reviewed their MKU 10 GHz transverter in *QST*. SSB Electronic offers transverters through the microwave range. ARRL reviewed their LT2S MkII in *QST*.

Table 5
Key Performance and Operational Specifications of Transverters Measured in the ARRL Lab

Model	*Band*	*Receive Gain (dB)*	*Noise Figure (dB)*	*Image Rejection (dB)*	*Output Power (W)*
Down East 144-28HP	2 meters	18	1.0	101	60
Down East 222-28	1.25 meters	17	0.8	103	25
Elecraft K144XV*	2 meters	25	1.0	106	10
Elecraft XV144	2 meters	25	1.0	70	20
Kuhne-Electronics MKU	10 GHz	20	1.2	Not measured	3
SSB Electronic LT2S MkII	2 meters	21	1.0	Not measured	20

*Internal option for K3 transceiver.

Fig 26 — The Down East Microwave 144-28HP transverter turns an HF transceiver into a 2 meter all-mode transceiver with sensitive receiver and 60 W output.

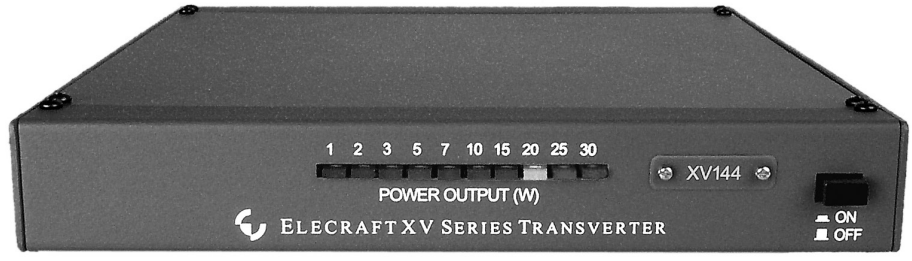

Fig 27 — Elecraft's XV144 2 meter transverter kit integrates seamlessly with their K2 and K3 HF transceivers. It works with other radios too, as long as they have appropriate input and output connections.

Transceivers for Use with Transverters

While almost any of the HF transceivers we have discussed can be made to operate with a transverter, some make for an easier fit than others. **Table 6** shows two transceivers in the low power (QRP) category that we excluded from our tables as discussed earlier. While both provide lower power on HF than our threshold, that is not a disadvantage for transverter use.

The key requirements for selecting a transceiver for transverter use are that they provide:

- Separate transmit and receive signal paths (not needed for all transverters).
- Control of RF output power down to low levels needed by most transverters. Having a separate low power transverter port avoids the chance that you will accidently apply 100 W on 20 meters, for example, to your transverter.
- Transmit-receive switching control available to switch the transceiver and transverter in proper sequence. While on many radios the TR control output designed for linear amplifier switching can be pressed into service, a dedicated port for transverters is a plus.

In addition, nice but not absolutely necessary features are:

- A frequency display that indicates the transverter operating frequency directly rather than the transceiver's tunable IF frequency.
- The ability to input a frequency calibration offset to compensate for any error in the transverter's heterodyne oscillator frequency.

While a number of the radios discussed earlier can meet these requirements, the two QRP sets described here can do it very at low cost.

The Elecraft K3 series radios are particularly well suited for transverter use. The addition of the KXV3 transverter interface board provides the desired low level transmit signal and needed ports for transverter interface. Table 6 shows the key parameters for a K3 optioned in the minimal configuration for transverter use. As provisioned, it can support automatically switching in up to nine transverters, each with its own frequency display (up to 25 GHz) and frequency offset.

Of course other options can be added if it is desired to use the transceiver as a 100 W HF transceiver as well. Some will also be helpful for transverter operation. For example, the internal 2 meter transverter option is a natural if microwave transverters are to be employed. A second receiver can be helpful to monitor an HF coordination frequency while attempting moonbounce or other sophisticated communication modes. A big advantage of the K3 is that it all is contained in a single compact box.

Also shown in Table 6 is the FlexRadio FLEX-1500 (**Fig 28**), the 5 W entry into this range of transceivers. It is aimed at the QRP HF operator or for use with VHF+ transverters but is controlled by *PowerSDR* software just as its more powerful sibling models. Both the FLEX-1500 and the full size FLEX-5000A (but not the FLEX-3000) offer dedicated transverter ports. With either, the *PowerSDR* software can be set up to display up to 15 transverter bands. Of course, in addition to the radio, a PC is also required for operation of the Flex radios.

Fig 28 — FlexRadio 5 W output FLEX-1500 software-defined radio. This radio operates with the same *PowerSDR* software as other FlexRadio SDRs, and provides features to make it compatible with multiple VHF/UHF/microwave transverters.

Table 6
Low Power HF Transceivers Particularly Suited for Transceiver Use

Model	*Street Price*	*Power*	*DSP*	*60 Meters*	*V/UHF*	*IMD DR (2 kHz)*
Elecraft K3/10F	$1370*	0.01 mW -10 W	IF	Yes	6 Meters (2 meters, $350)	103 dB
FlexRadio FLEX-1500	$650**	0.05 W - 5 W	IF, AF	Yes	6 Meters	86 dB

*Factory wired with transverter interface. Kit version and other options available.
**External PC required for operation and display.