2017

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 6 meters, 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 with limited HF privileges in addition to VHF 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, shortwave listening, or even spectrum analysis as well.

The information presented here is current as of mid-2016, but products and prices can change dynamically in such a competitive marketplace. Check dealer and manufacturer web pages, *QST* ads and Product Reviews (reviews from 1980 on are available to ARRL members at **www.arrl.org/product-review**) 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-2016, and subject to change (up or down). Prices do not include any coupons or limited time promotions. 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 around $1000 to $2000.

Upper mid-range — Desktop transceivers that cost 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 capabilities, 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 continuously introduced. 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

The following basic features are shared across every category of transceivers. 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 lower with reduced sensitivity) to the top of HF, sometimes well into VHF, depending on transceiver frequency coverage. This is useful to allow listening to international broadcast stations or other services, as well as the yet to be authorized LF and VLF amateur bands. It is also very 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 reduce or eliminate 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 — Most current generation transceivers offer DSP-based variable selectivity (filters). 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 (radioteletype) signal and not the frequencies between them, thus improving the detection probability in noise or interference.

• Dual VFO operation — All current designs offer instant selection of either of two operating frequencies to facilitate 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 automatic notch filtering — Most DSP-equipped transceivers provide for the reduction of impulse noise, such as that from ignition systems or power lines, as well as the elimination of steady interfering carriers.

• 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 bandwidths — 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 for narrower bandwidth modes, such as SSB, CW, and data modes, can be obtained by having narrower roofing filters available to match the transmit bandwidth, 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 effects of 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 horizontal 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*, 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. The display may be a conventional spectrum analyzer-style display with signal displayed as individual peaks, although *waterfall* displays are becoming more popular. In a waterfall display, signal strength is displayed as intensity or color on sequential frequency range scans.

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 output power levels, from the very compact and portable low power (QRP) transceivers to medium power radios. While the usual 100 W PEP output transceivers are the most popular, some transceivers provide 200 W PEP output or more.

• Audio equalization — Long a capability of amateurs interested in broadcast-quality voice signals, many 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 directly 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. The Elecraft K3S provides the capability to generate RTTY or PSK31 encoded data by entering Morse through the keyer paddles.

Entry Level Transceivers

As of mid-2016, there are six radios in full production that fall in or near this category. They include the Alinco DX-SR8T and DX-SR9T, the Icom IC-718, the Kenwood TS-480SAT and the Yaesu FT-450 and FT-857D. The Kenwood TS-480SAT and the Yaesu FT-857D are marketed as portable/mobile 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 $550 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 Alinco DX-SR9T is similar in capability, appearance and dimensions to the DX-SR8T, but adds an output containing the quadrature (I and Q channel) signal components. This can be used to support off-line signal processing in a PC running their *KG-TRX* software defined radio (SDR) software.

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 $600 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 now 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 optional bandwidth filters. Icom offers a narrower (1.9 kHz) bandwidth SSB filter for about $250. Other bandwidths for CW and SSB are available from aftermarket sources such as International Radio (**www.inrad.net**).

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 ($500), or the AH-4 for wire antennas

Fig 1 — The Alinco DX-SR8T desktop HF transceiver. This is the lowest price 100 W HF transceiver, as this is written.

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

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

($250, also usable for coax-fed 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 earlier 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-857D (**Fig 4**), is of the same generation as the IC-718, in that it uses analog IF filters and provides audio-based DSP. It offers the advantage of all-mode VHF and UHF operation in addition to HF.

The Kenwood TS-480SAT is priced near the top of this group. It 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.

The TS-480 has a removable front panel and an Ethernet port, making it remote-control ready right out of the box.

Fig 4 — The Yaesu FT-857D, an entry level transceiver with a mobile orientation and coverage up to 70 cm.

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 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-991 (**Fig 5**), 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 the rear or under a seat. All can be combined together in some way to operate as a single unit for home or field use.

Yaesu's FT-991 is well into the mid-range price category but with many advanced features, including dual roofing filters, a full-time spectrum scope and a touch-screen display. The Icom IC-7100 (**Fig 6**) has a separate front panel a bit different from others in that it is at an angle that can be easily viewed if used on a tabletop, or in some mobile arrangements. It also can be operated via touch screen, as well as via the usual controls. The Kenwood TS-480 (**Fig 7**) offers a choice of models with either an internal

Table 1
Transceivers in the Entry and Portable/Mobile Categories
All are 100 W PEP output transceivers unless otherwise noted.

Model	*Street Price*	*DSP*	*60 Meters*	*V/UHF*	*Ant Tuner*
Entry Level					
Alinco DX-SR8T	$ 550	No	Yes	No	No
Alinco DX-SR9T†	$ 650	No	Yes	No	No
Icom IC-718‡	$ 600	NB, NF	No	No	No
Kenwood TS-480SAT	$ 869	AF	Yes	6 Meters	Yes
Yaesu FT-450D‡	$ 750	IF	Yes	6 Meters	Yes
Yaesu FT-857D*	$ 824	AF	Yes	6, 2 m; 70 cm	No
Portable/Mobile					
Alinco DX-SR8T	$ 550	No	Yes	No	No
Alinco DX-SR9T†	$ 650	No	Yes	No	No
Icom IC-7100**	$1499	IF	Yes	6, 2 m; 70 cm	No
Kenwood TS-480SAT	$ 869	AF	Yes	6 Meters	Yes
Kenwood TS-480HX**	$1114	AF	Yes	6 Meters	No
Yaesu FT-857D*	$ 824	AF	Yes	6, 2 m; 70 cm	No
Yaesu FT-991‡*	$1300	IF	Yes	6, 2 m; 70 cm	Yes

†Provides I/Q output for DSP with external PC and sound card.
‡Single unit radio, others have separable control head.
*FT-857D is 50 W output on 2 meters, 20 W on 70 cm; IC-7100 is 50 W output on 2 meters, 35 W on 70 cm; FT-991 is 50 W output on 2 m and 70 cm.
**200 W output; requires one 40 A, or two 20 A power supplies.

Fig 5 — The Yaesu FT-991 HF, VHF and UHF transceiver offers a full color touch-display that features a full-time spectrum scope, as well as many other features.

Fig 6 — The Icom IC-7100 desktop HF, 6 and 2 meter and 70 cm transceiver. This radio offers a convenient angled front panel for desk or vehicle use and is the first with a touch screen, as well as knobs.

antenna tuner or a 200 W output transmitter, the only one in this price category to offer higher power.

Yaesu has recently announced their FT-891 HF and 6 meter mobile-oriented transceiver (**Fig 8**). This new mobile-focused transceiver has been FCC accepted, but as we write this, does not yet have an announced price or any lab test data. Unlike the FT-857D, which remains in the lineup, this is an HF focused radio, supporting 160 – 6 meter operation with CW, AM, and SSB modes and DSP processing.

Some of these radios can operate into the VHF and UHF range. Not only do most 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.

Fig 7 — 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.

Fig 8 — Yaesu FT-891 HF and 6 meter transceiver. This new mobile-focused transceiver has just been FCC accepted. Coverage includes SSB, CW, FM, and AM operation from 160 through 6 meters. (Photo courtesy of Yaesu)

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 during the review process, 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 or from reciprocal mixing noise from your frequency synthesizer. The higher the close-in dynamic range, the less likely you are to experience internally generated interference to stations you are trying to hear. (Dynamic range limitations are discussed in the **Receivers** chapter and in the **Test Equipment and Measurements** chapter.)

There are three primary dynamic range limitations tested during ARRL Product Review testing: blocking gain compression dynamic range, intermodulation distortion dynamic range, and reciprocal mixing dynamic range. The last was added to the test suite starting with the December 2007 Product Review, and is described in detail in a *QST* sidebar.[1] Since any of the three can be the limiting factor in dynamic range, the lowest is shown as "Min DR" in the tables for mid and higher-range transceivers, with the lowest dynamic range noted by BG for blocking, IM for intermodulation and RM for reciprocal mixing dynamic range.

It should be mentioned that, while data is shown for both traditional and software defined radio (SDR) receivers, their reactions to close in signals is somewhat different between the two platforms. SDR dynamic range can actually improve with multiple out of channel signals in the input. ARRL Lab testing procedures for SDR based receivers has been modified to make the results as comparable as possible.

Another consideration is transmitter linearity and dynamic range. Having an excellent receiver performance can be

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

Model	*Street Price*	*DSP*	*60 Meters*	*V/UHF*	*Ant Tuner*	*Min DR (dB) (2 kHz)*
Elecraft KX2+KXPA100	$1550	IF	Yes	No	$380	TBD
Elecraft KX3+KXPA100	$1850	IF	Yes	6 m, 2 m ($290)	$380	IM 100
Icom IC-7300	$1500	RF	Yes	6 Meters	Yes	TBD
Icom IC-7410	$1580	IF	Yes	6 Meters	Yes	RM 78
Kenwood TS-2000*	$1620	IF	No	6, 2 m; 70 cm	Yes	IM 57 ◊
Kenwood TS-2000X**	$1950	IF	No	6, 2 m; 70, 23 cm	Yes	IM 57 ◊
Kenwood TS-590SG	$1400	IF	Yes	6 Meters	Yes	RM 94**
TEN-TEC Eagle	TBD	IF	Yes	6 Meters	$249	RM 95
Yaesu FT-991	$1300	IF	Yes	6, 2 m; 70 cm	Yes	RM 75
Yaesu FTDX1200	$1380	IF	Yes	6 Meters	Yes	RM 81

*Includes a second receiver for simultaneous AM or FM reception only.
**Downconverting bands: 160, 80, 40, 20 and 15 meters. DR is generally less on the upconverting bands — 60, 30, 17, 12, 10 and 6 meters — as well as general coverage.
◊ Data taken before December 2007, only blocking and intermodulation DR data available.

Fig 9 — The Elecraft KX3, when paired with the Elecraft KXPA100 100 W output HF and 6 meter linear amplifier can serve as flexible HF and VHF home station, as well as a easy to carry portable station.

Fig 10 — The Icom IC-7300 is the first fully-SDR transceiver in a conventional HF transceiver package. Instead of a conventional superheterodyne conversion structure, digitization is performed directly at the RF signal frequency.

Mid-Range Transceivers (continued)

circumvented by having nearby transmitters with wide signals caused by various mechanisms in both CW and SSB modes. These factors are not reported here, but are shown in *QST* Product Reviews. For SSB, look for the level of intermodulation products and for CW the keying sidebands. The same frequency synthesizer phase noise that results in reciprocal mixing dynamic range on receive will result in wideband transmit signals as well. The best transceivers have good characteristics in both receive and transmit.

We have summarized some of the key features and parameters in **Table 2**. Newly added to the list are two mid-range packages from Elecraft. Elecraft offers two low powered portable transceivers, the KX2 (10 W) and KX3 (15 W), which are primarily designed for stand-alone field use, but if paired with the available Elecraft KXPA100 100 W HF and 6 meter linear amplifier become contenders for 100 W mid-range priced home station use. The KX2 offers HF operation only in a very compact package, although can be used with transverters for VHF use, while the somewhat larger KX3 (**Fig 9**) adds 160 and 6 meter coverage and has room for an optional internal 2 meter transverter. The linear amplifier offers a wider range antenna tuner option. Both the KX2 and KX3 include display screens that are strikingly similar to that of their bigger brethren, the K3S.

The Icom IC-7300 (**Fig 10**) represents the first example of fully-SDR architecture in a conventional-looking HF transceiver package. The ’7300 has a direct signal-frequency sampling front-end DSP processor that results in a simplified structure with excellent performance. Some of the equipment needs a bit of additional explanation. Note that none of the radios in Table 2 include a fully-capable second HF receiver, but the TS-2000 (**Fig 11**) does have a second receiver mainly for VHF FM use — perhaps handy for some who wish to monitor their local repeater while operating 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-590SG (see **Fig 12**) is a replacement for the TS-590S that offers a high performance down converting receive capability on some bands.

Other popular radios in this category include the Icom IC-7410 (**Fig 13**), TEN-TEC

Fig 11 — Kenwood TS-2000. This transceiver operates on MF, HF, VHF, UHF, as well as the 1.2 GHz band with an option (TS-2000X version), providing broad frequency coverage in a single package.

Fig 12 — The Kenwood TS-590SG offers a high performance receiver and many digital features.

Fig 13 — Icom IC-7410 covers HF and 6 meters with good receiver performance in a compact package.

Mid-Range Transceivers (continued)

Fig 14 — The TEN-TEC Eagle, a compact HF and 6 meter transceiver, provides excellent receive performance on all amateur bands.

Fig 15 — The Yaesu FTDX1200 HF and 6 meter transceiver features a colorful screen and spectrum display.

Eagle (**Fig 14**) and the Yaesu FTDX1200 (**Fig 15**). This radio has a colorful display screen and shares many features of the FTDX3000 shown in the next section.

Upper Mid-Range Transceivers

Transceivers in the upper mid-range group offer a number of choices between 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 Apache Labs ANAN 100/100D/200D (**Fig 16**) is one of a number of new offerings from this company providing a line of high quality SDR HF and 6 meter transceivers. These feature open-source software so user modifications or third party designs are possible.

The Elecraft K3S (**Fig 17**) provides excellent performance in this category and shows up in multiple categories because of its configuration flexibility. This radio is an upgrade of the original K3 including new synthesizer boards that deliver lower phase noise, a new internal pre-amp, replacing various external options, a new USB interface that replaces both the serial computer interface and the separate LINE IN and LINE OUT connections of the original. All modifications can be applied to the original K3, if desired.

Two distinct K3S versions are in this category including just the basic K3S 100 W components making a top-notch single receiver set. At a somewhat higher price point we list the initial dual-receiver configuration. A fully loaded K3S transceiver makes it into the "top drawer" category. Any can be purchased as kit units with just mechanical assembly required at some cost savings and upgrades can be added at any time.

To support remote-control operation, the K3S/0, a front-panel-only version, is available that can connect to the main K3S

Table 3
Transceivers in the Upper Mid-Range Category
All are 100 W transceivers. All have IF DSP and 60 meter coverage.

Model	*Street Price*	*2nd Rcvr*	*V/UHF*	*Ant Tuner*	*Min DR (dB) (2 kHz)*
Apache ANAN 100*	$2499	Yes	6 Meters	No	IM 96
Apache ANAN 100D*	$3299	Yes	6 Meters	No	IM 96
Apache ANAN 200D*	$3999	Yes	6 Meters	No	IM 96
Elecraft K3S/100F**	$2900	Yes	6 Meters (2 m $380)	$380	IM 103
Elecraft K3S/100F***	$3589	Yes	6 Meters	$380	IM 103
FlexRadio FLEX-6300*	$2499	Yes	6 Meters	$299	IM 92
Icom IC-7600	$3374	DW****	6 Meters	Yes	RM 82
Icom IC-9100	$2900	No	6, 2, 70 cm†	Yes	RM 77
TEN-TEC Omni VII	TBD	No	6 Meters	$300	IM 82 ◊
Yaesu FTDX3000	$2300	no	6 Meters	Yes	RM 82

*Requires a PC for operation.
**Basic model assembled 100 W unit. DR measured with optional 400 Hz roofing filter. Internal
***Assembled with dual receiver with 2700 Hz roofing filter in each receiver. DR measured with optional 400 Hz roofing filter.
****Dual watch — combines reception of two signals in same band into same audio channel.
†23 cm available as an option.
◊ Data taken before December 2007, only blocking and intermodulation data available.

Fig 16 — The Apache Labs ANAN 100D HF and 6 meter DSP transceiver is the first of a new line of open-source software defined radios.

Fig 17 — The Elecraft K3S HF and 6 meter transceiver. The flexibility of selectable options for this top performing radio gets it listed in two price categories.

via an Internet connection.

The FlexRadio FLEX-6300 (**Fig 18**) is the entry point into FlexRadio's *Signature Series* product line, with the other two radios in this series shown in the Top Drawer category. These radios all feature direct sampling and multiple simultaneous receiver operation, two channels for the '6300. A completely new software and display system has a different feel and look than previous FlexRadio SDRs, and a new Maestro control head is available.

The Icom IC-7600 (**Fig 19**) offers a "dual watch" receive capability that can monitor a second frequency in the same band, with both combined in the same audio channel. It also offers multiple roofing filters and a spectrum display.

The Icom IC-9100 (**Fig 20**) 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 TEN-TEC Omni VII (**Fig 21**) has a unique distributed roofing filter architecture that provides good receiver dynamic performance while still offering a general coverage receiver along with a single-scan panadapter display. The FTDX3000 (see **Fig 22**) is a lower priced, 100 W, single receiver version of "top drawer" FTDX5000.

Fig 18 — The FlexRadio FLEX-6300 is the entry point into a new line of software-defined radios that provides excellent performance, a built-in second receiver and optional antenna tuner.

Fig 19 — The Icom IC-7600 transceiver provides improved receiver performance through included 3, 6 and 15 kHz roofing filters.

Fig 20 — The Icom IC-9100 transceiver offers coverage of 1.8 through 440 MHz with an option for 1.2 GHz operation.

Upper Mid-Range Transceivers (continued)

Fig 21 — The TEN-TEC Omni VII offers good receiver performance and a single-pass panadapter.

Fig 22 — The Yaesu FTDX3000 offers high performance receiver, a 100 W transmitter and a colorful display screen.

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 K3S 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!

The Hilberling PT-8000A (**Fig 23**) provides professional-quality coverage of HF and VHF (6, 4, and 2 meters — with 4 meter transmit offered only in the European version). The PT-8000A offers superb analog receiver performance through the use of cascaded 12-pole crystal filters, followed by optional additional IF DSP selectivity and processing. At Icom's top end, the IC-7851 (**Fig 24**) features two high performance receivers, a low noise synthesizer, flexible panadapter, and a host of other high end features. The IC-7700 is basically an IC-7800 (the predecessor to the '7851) without

Fig 23 — The Hilberling PT-8000A offers a top quality HF and VHF transceiver from Germany.

Fig 24 — The Icom IC-7851 provides excellent performance and an extra flexible display system.

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*	*Min DR (dB) (2 kHz)*
Elecraft K3S/100F*	$5169*	Yes	100 W	6 Meters (2 m $380)	Yes	IM 103
FlexRadio FLEX-6500†**	$4299	Yes	100 W	6 Meters	$299	TBD
FlexRadio FLEX-6700**	$7499	Yes	100 W	6 Meters	Yes	IM 92
Hilberling PT-8000A	$15,500	Yes	200 W‡	6, 4, 2 meters	Yes	IM 100
Icom IC-7700	$6000	No	200 W	6 Meters	Yes	RM 78
Icom IC-7851	$12,990	Yes	200 W	6 Meters	Yes	IM 105
Kenwood TS-990S	$8000	Yes	200 W	6 Meters	Yes	RM 87
Yaesu FTDX5000MP	$4000	Yes	200 W	6 Meters	Yes	RM 104
Yaesu FTDX9000D	$8400	Yes	200 W	6 Meters	Yes	IM 87 ◊
Yaesu FTDX9000MP	$9300	Yes	400 W	6 Meters	Yes	IM 85

*Assembled; price can vary greatly with internal and external options. See Elecraft website for a full list of options and prices.
**Requires a PC for operation.
†Not yet tested in ARRL Lab.
‡100 W on VHF.
◊ Data take before December 2007, only blocking and intermodulation data available.

Top Drawer Transceivers (continued)

a second receiver — not something that is needed for every application.

Two SDR transceivers from FlexRadio are in this category. The FLEX-6500 and FLEX-6700 (**Fig 25**) offer additional features — four simultaneous receive and display channels for the '6500, eight for the '6700.

Yaesu offers two radios in this group. The Yaesu FTDX5000 (**Fig 26**) offers exceptional receiver close-in dynamic range measured in the ARRL Lab. It includes a more precise master oscillator and a 300 Hz roofing filter as well as a 200 W PEP transmitter. The FTDX9000D base unit also transmits at the 200 W level and includes a colorful multifunction TFT display. The FTDX9000MP is a 400 W PEP transmit version. Kenwood's top drawer TS-990S (**Fig 27**) offers two independent high performance receivers, a spectrum scope, and many other features.

Fig 25 — The FlexRadio Systems FLEX-6700 is a powerful SDR that can run up to 8 receivers simultaneously and has exceptional phase noise and dynamic range characteristics.

Fig 26 — The Yaesu FTDX5000 is a top-performing 200 W transceiver with a 300 Hz roofing filter. The unit on top is the optional SM-5000 station monitor.

Fig 27 — The Kenwood TS-990S HF and 6 meter transceiver offers dual high performance receivers and a spectrum scope.

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 from ours.

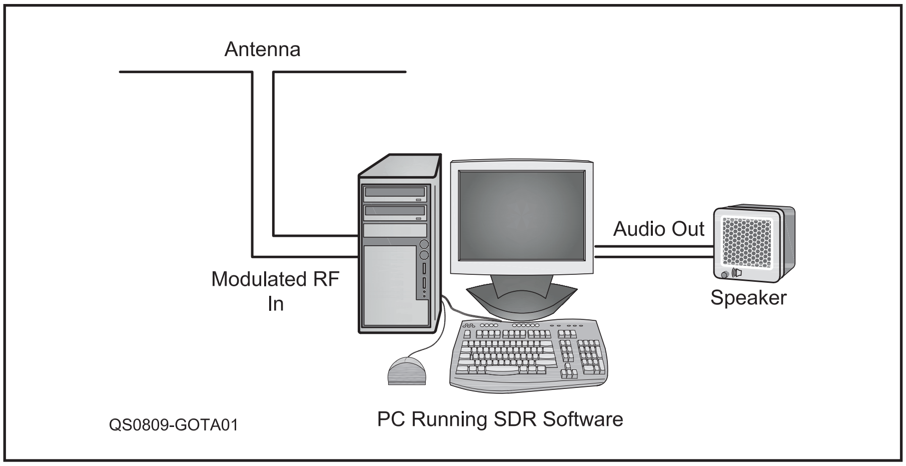

Fig 28 — Conceptual diagram of an ideal software-defined radio (SDR) receiver.

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.

While in the past, our utopian SDR was much easier to imagine than to construct, the newly introduced Icom IC-7300 is the first implementation of this principle we've seen in a package that looks and feels like a typical transceiver. Other manufacturers, including Apache Labs and FlexRadio offer "blank front panel" radios that also make use of SDR technology, but still require a separate PC for operation, control, and display functions. As a practical matter, a typical PC has some constraints that don't allow us to do everything we want within the PC. Manufacturers have thus moved the high-speed analog-to-digital conversion processing into their radios, leaving the more routine processing for the connected PC. While the IC-7300 can operate under the control of a PC, if desired, it includes all the processing needed for its functions and display.

The key to amateur SDR operation with a PC remains 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 typical computer sound card is usually the limiting point in terms of performance, as described below. More advanced SDRs, as described above, have the processing functionality built in and are thus able to take advantage of higher performance processing engines that can sample faster, allowing the direct processing of higher frequencies with each generation. They also can provide a higher dynamic range than typical sound cards.

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 28**. 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 can only output 100 mW or less.

It is for these reasons that the newest high performance SDR transceivers no longer depend on the PC for the A/D conversion process, instead using newly available high-speed processors within the SDR platform itself. While the PC's control screen may seem similar, the PC is now primarily used for the control and display functions with the "heavy lifting" happening in dedicated circuitry within the SDR.

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 best known are several generations of transceivers from FlexRadio Systems, which started with the SDR-1000, reviewed in *QST* in 2005. The current generation is a family of SDR systems called the FlexRadio Signature Series. Three radios from that

Software Defined Radios (continued)

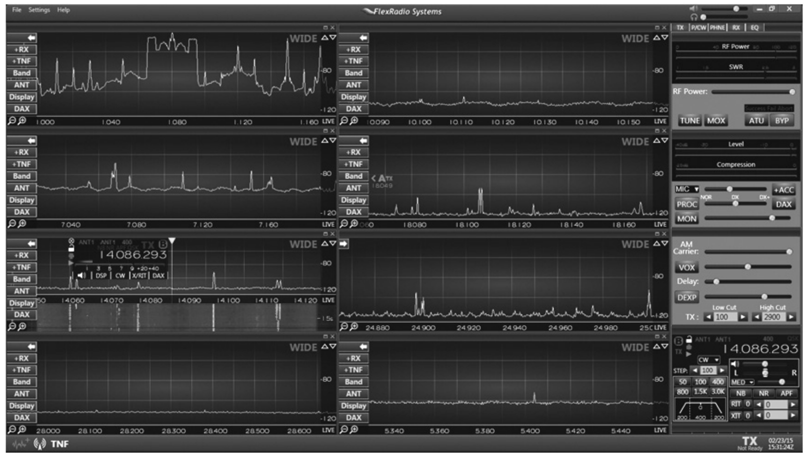

Fig 29 — One version of the main operating screen of *SmartSDR for Windows* operating software for the Flex 6000 series transceivers. In this case a FLEX-6700 has eight receivers and panadapters going simultaneously.

offering, the FLEX-6300, 6500, and 6700 appear in Tables 3 and 4. The front panel has no controls and all control functions are implemented by soft buttons on the software's computer screen. (**Fig 29** shows *SmartSDR for Windows*, used with the FlexRadio 6000 series radios.) FlexRadio also offers an optional FlexControl USB tuning knob that connects to the computer and the Maestro, a feature-laden control head. The 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 usable with open source *PowerSDR* software freely available under the GNU Public License. These include the Zeus ZS-1, 15 W HF SDR from SSB Electronics of Germany, the Anan 100/100D/200D 100 W SDRs and others from Apache Labs, and the modular High Performance SDR system available through Tucson Amateur Packet Radio (TAPR). There are also a number of very low cost SDRs available from various vendors. (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, such as the Elecraft K3S, TEN-TEC Eagle and Yaesu FTDX3000, for example, are provided with a mechanism to allow an easy end-user upgrade to new firmware revisions. The new Icom IC-7300 takes this to a new level with direct conversion at the signal frequency. These radios look like most any other pre-SDR radio in that they have front panels with knobs and dials and displays. 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.

While all radios in this group are designed primarily to operate without an external computer, they all can be computer controlled using aftermarket software, available from multiple developers. While this software can make them feel a bit like the radios in the other group, the operating parameter ranges are all set by the radio's internal operating firmware.

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 radios, 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 tables and product reviews (all *QST* Product Reviews since 1980 are provided 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 great preference for one person-to-machine interface over another. The *QST* Product Reviews attempt to capture some of the subjective impressions, at least as seen through the eyes of the reviewer.

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!

Extending HF Transceiver Coverage to Include VHF/UHF

Transceivers discussed so far include a wide range of features and operational capability. While some transceivers offer capability into the 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, many amateurs have heard enough about satellite communication or exotic beyond-line-of-sight propagation such as troposcatter, sporadic-E layer communication or moonbounce to want to try these activities. They take place using SSB, CW and narrow bandwidth digital modes, so a VHF/UHF FM transceiver won't do, although the FM satellites are almost as easy to use as the local repeater.

As noted previously, several HF transceivers also cover through the VHF bands and some into UHF at 70 cm. Among the entry level and portable/mobile radios, the Icom IC-7100, Yaesu FT- 857D and FT-991 all include 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-9100 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.

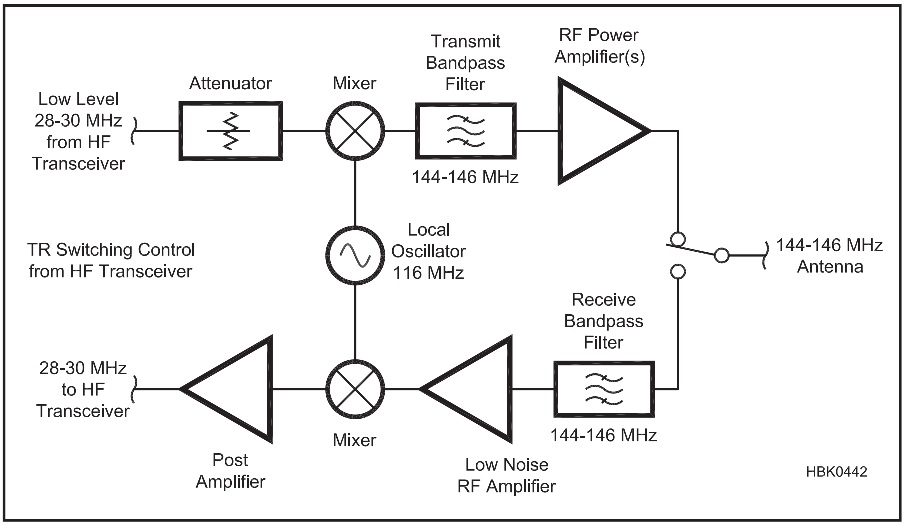

Fig 30 — Block diagram of a basic 2 meter to 10 meter transverter.

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 L144-28HP	2 meters	18	1.0	101	60
Down East L222-28	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

*Internal option for K3S transceiver.

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 typical 2 meter transverter is shown in **Fig 30**.

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 frequency range 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 carefully study 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 K3S is an example of an HF transceiver with well thought-out transverter provisions. It has dedicated, separate transverter input and output ports (an optional board required in the earlier K3). In addition, the band switch directly supports transverters just as if they were bands within 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 many 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 L144-28HP 2 meter transverter (**Fig 31**) and a similar transverter for 222 MHz, the L222-28.

Elecraft makes transverter kits from 6 meters to 70 cm including 1.25 meters. The ARRL reviewed their XV144 2 meter transverter kit (**Fig 32**). They also offer a 2 meter transverter, the K144XV, that is designed to fit within the K3 or K3S. With the addition of the K144XV, either K3 model covers 160 through 2 meters from a single compact box. The portable and trail oriented KX3 has provision for an internal 2 meter transverter.

Kuhne Electronics (DB6NT) makes transverters for many VHF/UHF/microwave bands. The ARRL reviewed their MKU 10 GHz transverter in *QST*.

A number of online-only vendors are beginning to offer VHF/UHF/Microwave transverters for sale. Check e-commerce sites for availability. VHF+ clubs and user groups may have more information about quality and availability of these units which are often made by small companies in batches.

Fig 31 — The Down East Microwave L144-28HP transverter turns an HF transceiver into a 2 meter all-mode transceiver with sensitive receiver and 60 W output.

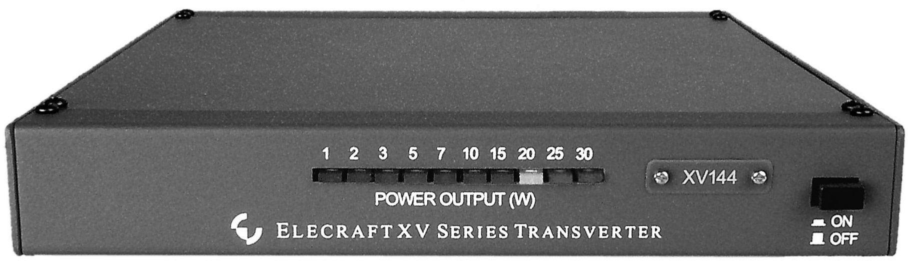

Fig 32 — Elecraft's XV144 2-meter transverter kit integrates seamlessly with their K2, K3 and K3S HF transceivers. It works with other radios too, as long as they have appropriate input and output connections.

[1]B. Allison, WB1GCM, "Reciprocal Mixing Testing: What Is It? (side bar to Product Review: ICOM IC-9100 MF/HF/VHF/UHF Transceiver)," *QST*, Apr 2012, p 55.

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 transceivers in the low power (QRP) category that we excluded from our tables as discussed earlier. While they 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 put 100 W on 20 meters, for example, into 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 QRP radios described here can do it very well at low cost.

The Elecraft K3S series radios are particularly well suited for transverter use. The new 'S version includes the functionality of the formerly optional KXV3 transverter interface board that provides the desired low level transmit signal and needed ports for transverter interface. Table 6 shows the key parameters for a K3S 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 K3S is that it all is contained in a single compact box. Even more compact is the KX3 (see Fig 9), a very portable DSP transceiver that has provision for 2 meters in the box. The front panel appears identical to its bigger brother, the K3S, but the total package is much smaller — think raincoat pocket. New this year is the KX2, an even smaller HF-only 10 W transceiver. Both the KX2 and KX3 include provision for nine transverter bands, but they require connection via a single transmit-receive port, and the output must be reduced to match the transverter input. The KX3, with its internal 6 meter and optional 2 meter coverage may have the edge for those who use microwave transverters with a a VHF IF frequency.

Also shown in Table 6 is the FlexRadio FLEX-1500 (**Fig 33**), 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. The FLEX-1500 offers dedicated transverter ports. 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 33 — FlexRadio 5 W output FLEX-1500 software-defined radio. This radio provides excellent performance in a small box and has provisions for use with transverters.

Table 6
Low Power HF Transceivers Particularly Suited for Transverter Use

Model	*Street Price*	*Power*	*DSP*	*60 Meters*	*V/UHF*	*Min DR (2 kHz)*
Elecraft K3S/10F	$2300*	0.01 – 10 W	IF	Yes	6 Meters (2 meters, $380)	103 dB
Elecraft KX3F	$1050*	0 – 15 W	IF	Yes	6 Meters (2 meters, $290)	100 dB
Elecraft KX2	$750*	0 – 10 W	IF	Yes	No	TBD
FlexRadio FLEX-1500**	$699	0.05 W – 5 W	IF, AF	Yes	6 Meters	86 dB
SSB Electronic ZS-1**	$1700	0.6 W – 15 W	IF	No	No	120 dB
Yaesu FT-817ND	$657	0.5 W – 5 W	AF	No	6 & 2 Meters, 70 cm	Not tested

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

The SSB Electronics Zeus ZS-1 (**Fig 34**) is a top performing 15 W SDR transceiver that should make a good transceiver for transverter use.

Fig 34 — The Zeus ZS-1 SDR from SSB Electronic is a high performing 15 W HF transceiver that could be a good candidate as a transverter companion.