2013

HF Transceiver Survey

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As with most major purchases, there are a wide range of choices 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 higher 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-2012, but both products and prices can change dynamically in such a competitive marketplace. Check dealer and manufacturer websites, *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-2012, 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, or other general purpose power supplies meeting the radio's specifications may 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 this book 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 continuously introduced. Watch for products announced or reviewed in *QST* and on the manufacturer and dealer websites.

Entry Level Transceivers

As of mid-2012, there are only 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. While the DX-SR8T is a new entry in this category, 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. 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 — just over $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 bandwidth CW filters, or for a 1.9 kHz bandwidth SSB filter (about $200 each). 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.

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 ($350). 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

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.

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. The internal antenna tuner that was an option with the original FT-450 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 newly designed, 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, by virtue of a price reduction, is now priced at the top of this group. It is defined in the following section, along with its somewhat higher priced 200 W sibling, the TS-480HX that trades the addition 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 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 the rear. 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-2000B is a version of the TS-2000 that incorporates a detachable 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.

Entry Level *Model*	*Street Price*	*DSP*	*60 Meters*	*V/UHF*	*Ant Tuner*
Alinco DX-SR8T	$530	No	Yes	No	No
ICOM IC-718*	$750	NB, NF	No	No	No
ICOM IC-7200*	$1050	IF	Yes	6 Meters	No
Kenwood TS-480SAT	$1000	AF	Yes	6 Meters	Yes
Yaesu FT-450D*	$980	IF	Yes	6 Meters	yes
Yaesu FT-857D	$840	AF	Yes	6, 2 m; 70 cm	No
Yaesu FT-897D*	$1000	AF	Yes	6, 2 m; 70 cm	No
Portable/Mobile					
ICOM IC-7000	$1300	IF	Yes	6, 2 m; 70 cm	No
ICOM IC-7200*	$1050	IF	Yes	6 Meters	No
Kenwood TS-480SAT	$1000	AF	Yes	6 Meters	Yes
Kenwood TS-480HX**	$1140	AF	Yes	6 Meters	No
Kenwood TS-2000B***	$1500	IF	Yes	6, 2 m; 70 cm	Yes
Yaesu FT-857D	$840	AF	Yes	6, 2 m; 70 cm	No
Yaesu FT-897D*	$1000	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 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 because of its configuration flexibility. Also in this group is the FlexRadio FLEX-3000 (**Fig 8**) software-defined radio. This transceiver is very much like its larger sibling, the FLEX-5000, but 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 the second receiver and antenna options of its larger brother, 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 2 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 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**)

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 the same *PowerSDR* software as the FLEX-5000 series, 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*	*Tuner*	*IMD DR (2 kHz)*
Elecraft K3/100F	$2250*	IF	Yes	6 Meters	$330	103 dB
FlexRadio FLEX-3000	$1699	IF	Yes	6 Meters	No	95 dB
ICOM IC-7410	$1950	IF	Yes	6 Meters	Yes	88 dB
Kenwood TS-2000**	$1550	IF	No	6, 2 m; 70 cm	Yes	57 dB
Kenwood TS-2000X**	$2000	IF	No	6, 2 m; 70, 23 cm	Yes	57 dB
Kenwood TS-590S	$1650	IF	Yes	6 Meters	Yes	97 dB***
Ten-Tec Eagle	$1819	IF	Yes	6 Meters	$249	98 dB
Ten-Tec Jupiter	$1939	IF	Yes	No	Yes	63 dB
Yaesu FT-950	$1450	IF	Yes	6 Meters	Yes	71 dB

*Base assembled 100 W unit. IMD measured with optional 400 Hz roofing filter. Kit version also available.
**Includes a second receiver for simultaneous AM or FM reception only.
***Downconverting bands only; non-downconverting bands, 82 dB typical

Mid-Range Transceivers (continued)

Fig 9 — Kenwood TS-2000. This transceiver operates on MF, HF, VHF and UHF into microwaves with an option, providing broad frequency coverage in a single package.

Fig 10 — The Kenwood TS-590S offers a high performance receiver on the key 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.

offers a high performance receive capability on the most popular amateur HF bands and many digital features in a compact envelope.

The ICOM IC-7410, see **Fig 11**, has replaced the venerable IC-746Pro in ICOM's HF lineup. It brings improved receiver dynamic performance and the 60 meter channels, as well as 6 meter operation, but no

Mid-Range Transceivers (continued)

longer includes 2 meter operation.

Other popular radios in this category include the Ten-Tec Jupiter, recently upgraded with a new display and shown in **Fig 12**, the newer Ten-Tec Eagle (**Fig 13**) and the Yaesu FT-950 (**Fig 14**) sharing many features of the mid range FT-2000, but with a single receiver channel.

Fig 12 — The Ten-Tec Jupiter HF transceiver provides solid basic HF coverage in a modern DSP driven configuration.

Fig 13 — The Ten-Tec Eagle, a compact HF and 6 meter transceiver provides excellent receive performance on all amateur bands.

Fig 14 — The Yaesu FT-950 HF and 6 meter transceiver provides most of the FT-2000 functionality except the second receiver.

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 Ten-Tec Omni VII (**Fig 15**) uses a unique distributed roofing filter architecture that provides very good receiver dynamic performance while still offering a general coverage receiver along with a single-scan panadapter display. The ICOM IC-9100 (**Fig 16**) 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.

Table 3
Transceivers in the Upper Middle Range Category

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

Model	*Street Price*	*2nd Rcvr*	*V/UHF*	*Tuner*	*IMD DR (2 kHz)*
Elecraft K3/100F	$2910*	Yes	6 Meters	$340	103 dB
FlexRadio FLEX-5000A	$2799**	$699	6 Meters	$299	99 dB
ICOM IC-7600	$3850	DW***	6 Meters	Yes	88 dB
ICOM IC-9100	$3650	No	6, 2, 70 cm†	Yes	87 dB
Ten-Tec Omni VII	$2795	No	6 Meters	$300	82 dB
Yaesu FT-2000‡	$2650	Yes	6 Meters	Yes	69 dB

*Assembled with dual receiver with 2700 Hz roofing filter in each receiver. IMD measured with optional 400 Hz roofing filter. Many other options are available, including VHF and UHF transverters. Options may be added at any time.
**Requires a PC for operation.
***Dual watch — combines reception of two signals in same band into same audio channel.
†23 cm available as an option.
‡Includes internal power supply. A 200 W version, the FT-2000D, is available for $3550 including external supply.

Fig 15 — The Ten-Tec Omni VII offers very good receiver performance and a single-pass panadapter.

Fig 16 — The ICOM IC-9100H transceiver offers coverage of 1.8 through 440 MHz with an option for 1.3 GHz operation.

Upper Mid-Range Transceivers (continued)

The Yaesu FT-2000 (**Fig 17**) is the only transceiver in this group that comes equipped with a second receiver and two audio channels. The second receiver is an analog design that seems quite good, although its operating bandwidth is set by optional crystal lattice filters. The FlexRadio 5000A (**Fig 18**) is a software-defined radio that requires a separate PC to operate it. Controls and displays are implemented via the PC. This transceiver can make use of an optional independent identical second receiver.

The ICOM IC-7600 (**Fig 19**) 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 2 with a single receiver and in Table 3 with a dual receiver. The K3 is also offered in kit form at significant savings.

Fig 17 — The Yaesu FT-2000 offers a second HF SSB receiver as standard equipment. A 200-W version (the D model) is available.

Fig 18 — 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.

Fig 19 — 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 summarized in **Table 4**. 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.

The Ten-Tec Orion II (**Fig 20**) has been a mainstay of this category, with its excellent main channel receive performance and smooth CW break-in operation. It offers the narrowest of first IF roofing filters in its amateur band-only main receiver and general coverage in its sub-receiver. A new option is a high performance second receiver module that matches the performance of the primary receiver.

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 series (**Fig 21**) offers the highest receiver near-in dynamic range measured in the ARRL Lab. The base FTDX5000 has the station monitor as an option, while it is included in the FTDX5000D and FTDX-5000MP. The FTDX5000MP also provides a more precise master oscillator and the 300 Hz roofing filter that is an option in the others. All FTDX5000 models provide 200 W PEP transmitters. The FTDX9000 base unit also transmits at the 200 W level and offers available display options. The FTDX9000 also offers a 400 W (MP suffix) PEP transmit version. At ICOM's top end, the IC-7700 is basically a top of the line IC-7800 (**Fig 22**) without a second receiver — not something that is needed for every application.

Announced, but not yet generally available as we write this, are a completely new transceiver from Kenwood, the TS-990S, a new family of modular software defined transceivers from FlexRadio, the FLEX-6000 series with "Smart SDR," the Yaesu FTDX3000 and a reintroduction of the Hilberling PT-8000 transceivers. All are likely to be in this price category.

Fig 20 — The Ten-Tec Orion II offers excellent receive dynamic range through very narrow HF roofing filters in its main receiver.

Fig 21 — The Yaesu FTDX5000 is one of a family of top-performing 200 W transceivers expandable with a 300 Hz roofing filter and multiple display options. The unit on top is the companion SM-5000 station monitor.

Fig 22 — The ICOM IC-7800 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*	*Tuner*	*IMD DR (2 kHz)*
Elecraft K3/100F*	$5220*	Yes	100 W	6 Meters	Yes	103 dB
ICOM IC-7700	$7200	No	200 W	6 Meters	Yes	87 dB
ICOM IC-7800	$12,500	Yes	200 W	6 Meters	Yes	86 dB
Ten-Tec Orion II	$4395	Yes	100 W	No	$300	94 dB
Yaesu FTDX5000	$5350	Yes	200 W	6 Meters	Yes	103 dB
Yaesu FTDX5000D	$5550	Yes	200 W	6 Meters	Yes	103 dB
Yaesu FTDX5000MP	$5950	Yes	200 W	6 Meters	Yes	103 dB
Yaesu FTDX9000C	$5800	$1950***	200 W	6 Meters	Yes	79 dB
Yaesu FTDX9000D	$10,400	Yes	200 W	6 Meters	Yes	87 dB
Yaesu FTDX9000MP	$11,700	Yes	400 W	6 Meters	Yes	85 dB

*Assembled including all options, not including available stand alone panadapter or VHF and UHF transverters. Options may be added at any time.
**Includes built in PC.
***Must be specified at time of transceiver order, Other options are also available at time of purchase.

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.

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.

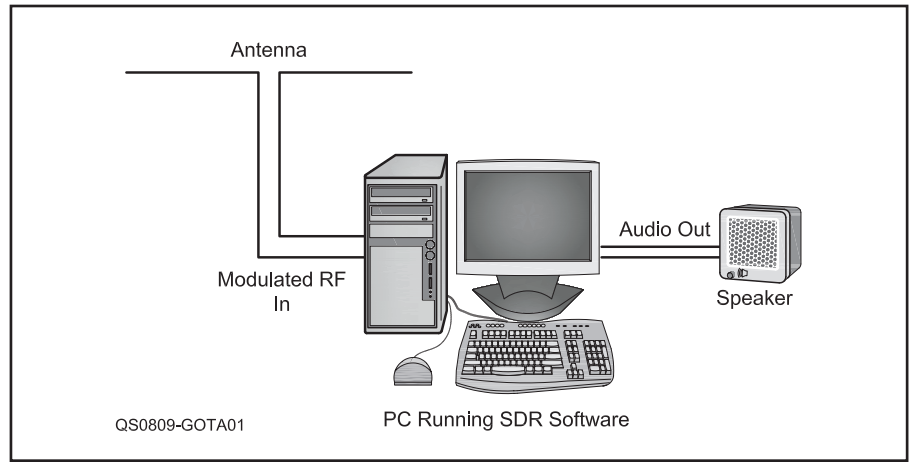

Fig 23 — Conceptual block diagram of an ideal software-defined radio (SDR) receiver.

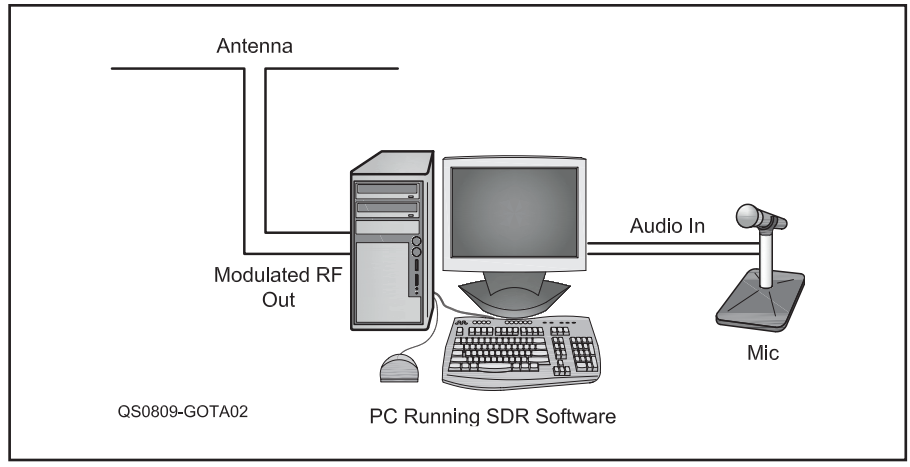

Fig 24 — Conceptual block diagram of the transmit side of an ideal SDR transceiver.

The key to amateur SDR operation with a PC is the sound card. This card, or sometimes an external interface device, can accept an analog signal and convert it to a digital one for processing. Advanced SDRs such as some of those from FlexRadio have the processing functionality built in.

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 23**. 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 24**) 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 hard-

ware 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. The front panel has no controls and all control functions are implemented by soft buttons on the *PowerSDR* software's computer screen (**Fig 25**), or via pointing and knob devices that connect to the computer.

There are a number of similarly configured radios usable with the same open source *PowerSDR* software freely available from FlexRadio under the GNU Public License. These include the modular High Performance SDR system available through Tucson Amateur Packet Radio (TAPR), and some other very low cost, but no longer available SDRs such as the Firefly and Softrock-40. (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.)

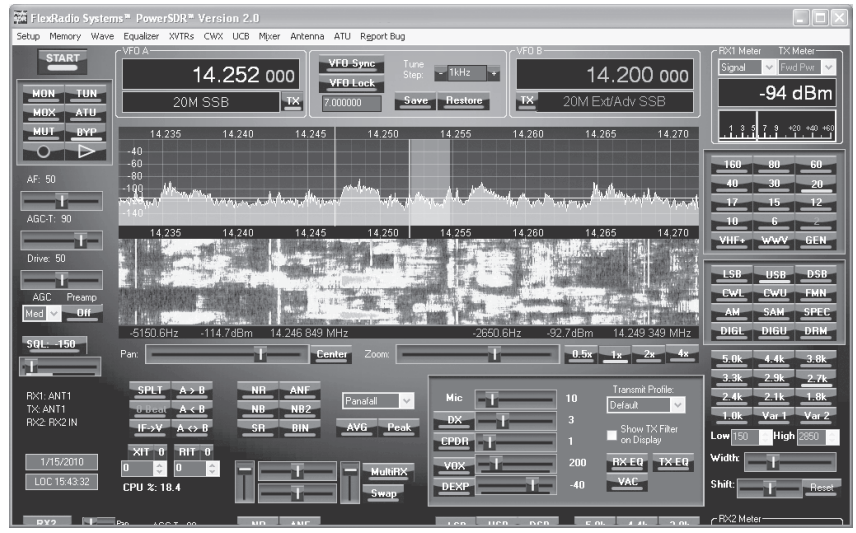

Fig 25 — One version of the main operating screen of PowerSDR operating software.

The "Looks Like a Radio" Approach

Many current radios are actually built as SDRs. Some, such as the Elecraft K3, ICOM IC-7800, Ten-Tec Orion and Yaesu FT-2000, for example, 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.

While all radios in this group are primarily designed 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 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 tables and product reviews (all *QST* Product Reviews since 1980 are provided to ARRL members on the *QST* website 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.

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 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 FM satellites are almost as easy to use as the local repeater. As noted previously, a number of HF transceivers, cover through the VHF bands through 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 support 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.

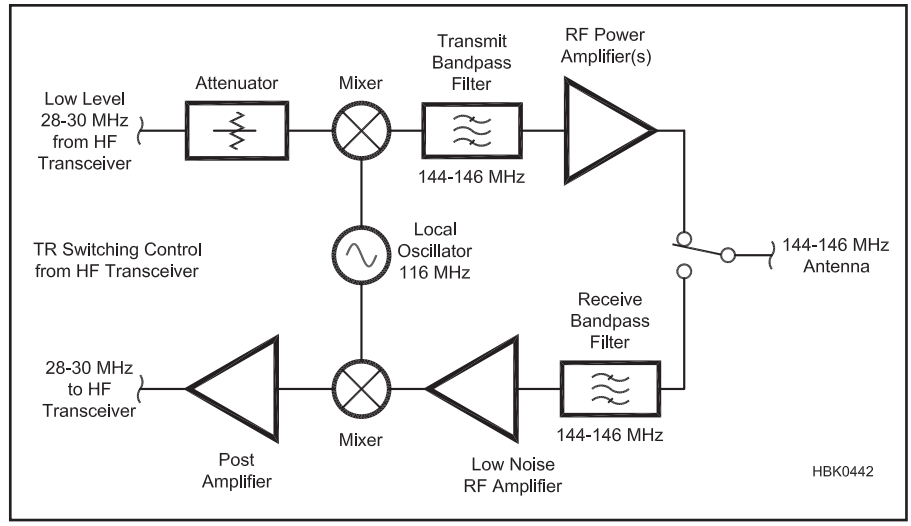

Fig 26 — Block diagram of a basic 2 meter to 10 meter transverter.

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 26**.

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 from 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 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 144-28HP 2 meter transverter in *QST*, see **Fig 27**. 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 28**). They also offer a 2 meter transverter, the K144XV, that is designed to fit within the K3. With the K144XV installed, the K3 covers 160 through 2 meters. The K144XV was reviewed in *QST*.

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 27 — 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.

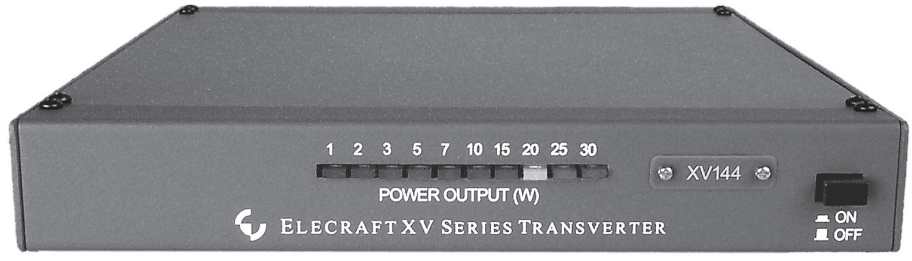

Fig 28 — Elecraft's XV144 2-meter transverter kit integrates seamlessly with their K2 and K3 HF transceivers. It works with other radios too, as long as they have appropriate input and output connections. The internal K144XV 2 meter transverter is another option for Elecraft K3 owners.