As with most major purchases, there is 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 survey, presented by Joel R. Hallas, W1ZR, 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 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-2011, but both products and prices can change dynamically in such a competitive marketplace. Check dealer and manufacturer websites, QST ads and QST Product Reviews as you get close to making a choice. QST Product Reviews are available to ARRL members on the ARRL website at www.arrl.org/product-review. The page can be searched by manufacturer name or magazine issue.

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-2011, 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 more than $4000.
- **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 a maximum current of 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 “matching” power supply, or other general purpose power supplies meeting specifications may be used.

One of the most-active areas of transceiver development is in the application of digital signal processing and software-defined radios. These technologies are given their own chapter of *The ARRL Handbook* for that reason, as well as a long sidebar on the subject in the Receivers chapter.

It is worth continuing to educate yourself on these technologies as they are displacing a significant amount of analog circuitry.

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 in QST and on the manufacturer and dealer websites.
Entry Level Transceivers

As of mid-2011, there are only five radios in full production that fall in this category, the Alinco DX-SR8T, ICOM IC-718 and IC-7200 and the Yaesu FT-450D and the FT-897D. The IC-7200 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 currently the lowest priced 100 W HF transceiver on the market at about $560. While it is a new design and has an attractive price, it doesn’t offer some features that many operators expect nor does it take advantage of many of the digital signal processor features common in most new radios.

The IC-718, shown in Fig 2, is available at a price near the bottom of the range, about $640 at this writing. The IC-718 offers a lot of bang for the buck, but it 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 includes an audio DSP add-on module that offers digital noise reduction and a digital notch filter and 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. An additional slot is provided for one of two optional CW bandwidth filters (250 or 500 Hz; about $200 each), or for a narrower (1.8 kHz) or wider (3.3 kHz) bandwidth SSB filter at about $200. While they can be installed later, the filters do need to be soldered to the PC board, requiring some experience with disassembling equipment as well as the ability to solder electronic components on a printed circuit board. 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 ($460), or the AH-4 for wire antennas with SWR typically up to 10:1 ($295). 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 a fairly recent addition to the Yaesu line of current generation transceivers. The FT-450 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 three fixed bandwidth choices each for CW, SSB and AM. These are all built in without having to buy options. The FT-450D can be purchased without an internal antenna tuner for around $900. An internal antenna tuner can be added at any time for about $150.

The FT-897D (see Fig 4) and IC-7200 (see Fig 5) are in a way opposites to the previous transceivers of the 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.

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.
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 a 100 W output radio with 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 that I’ve used will be confused with a high fidelity audio system.

Table 1

| Transceivers in the Entry and Portable/Mobile Categories |
|---------------------------------|----------------|---------------|----------------|--------------|
| **Model**                       | **Street Price** | **DSP**       | **60 Meters**  | **V/UHF**    |
| Alinco DX-SR8T                  | $560            | None          | Yes            | No           | No           |
| ICOM IC-718                     | $640            | NB, NF        | No             | No           | No           |
| ICOM IC-7200*                   | $1030           | IF            | Yes            | 6 Meters     | No           |
| Yaesu FT-450D*                  | $900            | IF            | Yes            | 6 Meters     | $100         |
| Yaesu FT-897D*                  | $940            | AF            | Yes            | 6, 2 m; 70 cm| No           |
| **Portable/Mobile**             |                 |               |                |              |
| Alinco DX-SR8T                  | $560            | None          | Yes            | No           | No           |
| ICOM IC-7000                    | $1240           | IF            | Yes            | 6, 2 m; 70 cm| No           |
| ICOM IC-7200*                   | $1030           | IF            | Yes            | 6 Meters     | No           |
| Kenwood TS-480SAT               | $980            | AF            | Yes            | 6 Meters     | Yes          |
| Kenwood TS-480HX**              | $1080           | AF            | Yes            | 6 Meters     | No           |
| Yaesu FT-857D                   | $800            | AF            | Yes            | 6, 2 m; 70 cm| No           |
| Yaesu FT-897D*                  | $940            | 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.

Fig 6 — Kenwood TS-480HX, the only transceiver in this category with a 200 W transmitter.
**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 most important indicator for good performance in the midst of strong signals such as during a contest or when chasing DX. When the band is crowded with very strong signals operating nearby, you can experience interference generated in your receiver 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. A recent addition to this grouping 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 tuner or VHF/UHF transverter options of its larger brother, it will look the same on the PC screen and likely sound the same to the far end.

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

---

**Table 2**

<table>
<thead>
<tr>
<th>Model</th>
<th>Street Price</th>
<th>DSP</th>
<th>60 Meters</th>
<th>V/UHF</th>
<th>Tuner</th>
<th>IMD DR (2 kHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elecraft K3/100F</td>
<td>$2200*</td>
<td>IF</td>
<td>Yes</td>
<td>6 Meters</td>
<td>$330</td>
<td>103 dB</td>
</tr>
<tr>
<td>FlexRadio Flex-3000</td>
<td>$1700</td>
<td>IF</td>
<td>Yes</td>
<td>6 Meters</td>
<td>No</td>
<td>95 dB</td>
</tr>
<tr>
<td>ICOM IC-7410</td>
<td>$1950</td>
<td>IF</td>
<td>No</td>
<td>6 Meters</td>
<td>Yes</td>
<td>88 dB</td>
</tr>
<tr>
<td>Kenwood TS-590</td>
<td>$1750</td>
<td>IF</td>
<td>Yes</td>
<td>6 Meters</td>
<td>Yes</td>
<td>97 dB</td>
</tr>
<tr>
<td>Kenwood TS-2000**</td>
<td>$1500</td>
<td>IF</td>
<td>No</td>
<td>6, 2 m; 70 cm</td>
<td>Yes</td>
<td>57 dB</td>
</tr>
<tr>
<td>Kenwood TS-2000X**</td>
<td>$1940</td>
<td>IF</td>
<td>No</td>
<td>6, 2 m; 70, 23 cm</td>
<td>Yes</td>
<td>57 dB</td>
</tr>
<tr>
<td>Ten-Tec Eagle</td>
<td>$1795</td>
<td>IF</td>
<td>Yes</td>
<td>6 Meters</td>
<td>$200</td>
<td>98 dB</td>
</tr>
<tr>
<td>Ten-Tec Jupiter</td>
<td>$1595</td>
<td>IF</td>
<td>Yes</td>
<td>No</td>
<td>$300</td>
<td>63 dB</td>
</tr>
<tr>
<td>Yaesu FT-950</td>
<td>$1370</td>
<td>IF</td>
<td>Yes</td>
<td>6 Meters</td>
<td>Yes</td>
<td>71 dB</td>
</tr>
</tbody>
</table>

*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.**
handy while operating on split frequencies and a popular option with DX chasers. Other popular radios in this category include the Ten-Tec Jupiter, recently upgraded with a new display and shown in Fig 10, and the Yaesu FT-950 (Fig 11) sharing many features of the mid range FT-2000, but with a single receiver channel.

Three new transceivers have joined this category since the 2011 edition—and each is worth some discussion. The ICOM IC-7410, see Fig 12, has replaced the venerable IC-746Pro in ICOM’s HF lineup. It brings

Mid-Range Transceivers (continued)

— solid basic HF coverage in a modern DSP driven configuration.

Fig 11 — The Yaesu FT-950 HF and 6 meter transceiver provides most of the FT-2000 functionality except it doesn’t include a second receiver.

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.
**Mid-Range Transceivers**

(continued)

improved receiver dynamic performance and the 60 meter channels, as well as 6 meter operation, but no longer includes 2 meter operation. The Kenwood TS-590 (Fig 13) is a compact HF and 6 meter transceiver with the excellent close-in dynamic range receiver performance expected by serious contesters and DX operators on the primary HF bands. It switches to a different receiver architecture with somewhat less performance, but more bandwidth flexibility on other bands. The Ten-Tec Eagle, Fig 14, is in an even more compact package and also brings top receiver performance on all its bands.

Fig 12 — The ICOM IC-7410, has replaced the venerable IC-746Pro in ICOM’s HF lineup.

Fig 13 — The Kenwood TS-590 is a compact HF and 6 meter transceiver with excellent close-in dynamic range receiver performance on the primary HF bands.

Fig 14 — The Ten-Tec Eagle, an even more compact package with top receiver dynamic performance on all its bands.
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) includes a unique distributed roofing filter architecture that provided 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.

The Yaesu FT-2000 (Fig 17) and the Elecraft K3 (Fig 7), with options noted in this category, provide a second HF receiver. The Flex-5000A can also be equipped with a second receiver, but its price then moves it into the next category. Each two receiver arrangement provides two audio channels allowing one receiver in each ear or in each of two stereo speakers — a great feature for chasing DX stations that are operating on split frequencies.

### Table 3

<table>
<thead>
<tr>
<th>Model</th>
<th>Street Price</th>
<th>2nd Rcvr</th>
<th>V/UHF Tuner</th>
<th>IMD DR (2 kHz)</th>
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<tr>
<td>Elecraft K3/100F</td>
<td>$2860*</td>
<td>Yes</td>
<td>6 Meters</td>
<td>$340</td>
</tr>
<tr>
<td>FlexRadio Flex-5000A</td>
<td>$2800**</td>
<td>$699</td>
<td>6 Meters</td>
<td>$299</td>
</tr>
<tr>
<td>ICOM IC-7600</td>
<td>$3650</td>
<td>No</td>
<td>6 Meters</td>
<td>Yes</td>
</tr>
<tr>
<td>ICOM IC-9100</td>
<td>$3800</td>
<td>No</td>
<td>6, 2, 70 cm**</td>
<td>Yes</td>
</tr>
<tr>
<td>Ten-Tec Omni VII</td>
<td>$2695</td>
<td>No</td>
<td>6 Meters</td>
<td>Yes</td>
</tr>
<tr>
<td>Yaesu FT-2000***</td>
<td>$2530</td>
<td>Yes</td>
<td>6 Meters</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*Assembled with dual receiver with 2700 Hz roofing filter in each receiver. IMD measured with optional 400 Hz roofing filter ($130), many other options are available to a maximum equipped price of $5220, not including available VHF and UHF transverters. Options may be added at any time.

**23 cm available as an option.

***Includes internal power supply. A 200 W version, the FT-2000D, is available for $3130 including external supply.
Upper Mid-Range Transceivers (continued)

The second receiver in the K3 is identical to its primary receiver, while that of the FT-2000 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 as shown in Fig 19. The ‘5000 series offers internal options that provide a second receiver, internal antenna tuner or a 60 W VHF/UHF transverter.

The ICOM IC-7600 (Fig 20) 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 mechanical assembly only required kit form at significant savings.
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.

The Ten-Tec Orion II (Fig 21) 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.

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 the Yaesu FTDX5000 series (Fig 22) with a top performing receiver and the FTDX9000. Both have base units at the 200 W level and both offer available additional display options. The FTDX9000 also offers a 400 W (MP suffix) version. At ICOM’s top end, the IC-7700 is basically a top of the line IC-7800 (Fig 23) without a second receiver — not something that is needed for every application.

![Fig 21 — The Ten-Tec Orion II offers excellent receive dynamic range through very narrow HF roofing filters in its main receiver.](image)

![Fig 22 — 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.](image)

![Fig 23 — The ICOM IC-7800 provides excellent performance and an extra flexible display system.](image)

### Table 4

<table>
<thead>
<tr>
<th>Model</th>
<th>Street Price</th>
<th>Price</th>
<th>2nd Receiver</th>
<th>Power</th>
<th>V/UHF</th>
<th>Tuner</th>
<th>IMD DR (2 kHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elecraft K3/100F*</td>
<td>$5220*</td>
<td></td>
<td>Yes</td>
<td>100 W</td>
<td>6 Meters</td>
<td>Yes</td>
<td>103 dB</td>
</tr>
<tr>
<td>FlexRadio Flex-5000+**</td>
<td>$4740**</td>
<td></td>
<td>Yes</td>
<td>100 W</td>
<td>6, 2, 70 cm</td>
<td>Yes</td>
<td>99 dB</td>
</tr>
<tr>
<td>ICOM IC-7700</td>
<td>$6800</td>
<td>$100 W</td>
<td>No</td>
<td>200 W</td>
<td>6 Meters</td>
<td>Yes</td>
<td>87 dB</td>
</tr>
<tr>
<td>ICOM IC-7800</td>
<td>$12,000</td>
<td>Yes</td>
<td>Yes</td>
<td>200 W</td>
<td>6 Meters</td>
<td>Yes</td>
<td>86 dB</td>
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<tr>
<td>Ten-Tec Orion II</td>
<td>$4295</td>
<td>Yes</td>
<td>Yes</td>
<td>100 W</td>
<td>No</td>
<td>$300</td>
<td>94 dB</td>
</tr>
<tr>
<td>Yaesu Ftdx5000</td>
<td>$5090</td>
<td>Yes</td>
<td>Yes</td>
<td>200 W</td>
<td>6 Meters</td>
<td>Yes</td>
<td>103 dB</td>
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<tr>
<td>Yaesu Ftdx5000MP</td>
<td>$5820</td>
<td>Yes</td>
<td>Yes</td>
<td>200 W</td>
<td>6 Meters</td>
<td>Yes</td>
<td>103 dB</td>
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<tr>
<td>Yaesu Ftdx9000 C</td>
<td>$4700</td>
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<td>Yes</td>
<td>200 W</td>
<td>6 Meters</td>
<td>$1950</td>
<td>79 dB</td>
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<td>Yaesu Ftdx9000D</td>
<td>$9750</td>
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<td>Yes</td>
<td>200 W</td>
<td>6 Meters</td>
<td>Yes</td>
<td>87 dB</td>
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<tr>
<td>Yaesu Ftdx9000MP</td>
<td>$10,550</td>
<td>Yes</td>
<td>Yes</td>
<td>400 W</td>
<td>6 Meters</td>
<td>Yes</td>
<td>85 dB</td>
</tr>
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</table>

*Assembled including all internal options. Options may be added at any time.

**Flex 5000-RX2-ATU-VU5K. With RX2 second receiver, ATU tuner and VU5K 2 meter and 70 cm 60 W transverter. Other combinations available.

***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 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.”” (From FCC Report and Order 01-264, released Sep 14, 2001.) In this context, they are envisioning radios that can be modified at the factory by using different software to meet different requirements. While they allow for field changes, the FCC’s focus is different than ours.

**SDR IN THE AMATEUR WORLD**

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

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

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

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

The key to amateur SDR operation with a PC is the 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 those from FlexRadio have the 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 24. 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 25) can only output 100 mW or less.

Thus we are faced with the need to insert some external processing functions outside the PC. These will be used, at a minimum, to translate the frequency range we wish to use to one that the sound card can deal with on the receive side. On the transmit side, we will need to translate the frequency range up to the desired portion of the radio spectrum and increase the signal to our desired transmit power level.

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

The “Blank Front Panel” Architecture

Radios marketed as SDRs tend to be of this type. The classic is the FlexRadio Flex-5000A, reviewed in QST for July 2008. The front panel has no controls and all control functions are implemented by soft buttons on the PowerSDR software’s computer screen (Fig 26), or via pointing and knob devices that connect to the computer.

There are a number of similarly configured radios useable with the same open source PowerSDR software freely available from FlexRadio under the GNU Public License. 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.)

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 skilled 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.

Making a Selection

You know the facts — how can you choose? Looking at tables and product reviews 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 and Transverters 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 except for some low orbit FM satellites.

Two current full-size HF transceivers extend operation well into the VHF and UHF regions, 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.

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 27.

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

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

TRANSVERTER DESIGN

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

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

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

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

If building a transverter from scratch is not for you, a number of manufacturers produce assembled or kit transverters for 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 28.

Elecraft makes external transverter kits from 6 meters to 70 cm including 1.25 meters. The ARRL reviewed their XV144 2 meter transverter in QST. They also offer a 2 meter transverter that fits within the K3 transceiver.

Flexradio offers an internal option for the Flex5000 HF and 6 meter software defined transceiver that serves as a 2 meter and 70 cm transverter.

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, see Fig 29. SSB Electronic offers transverters through the microwave range. ARRL reviewed their LT2S MkII in QST.

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### Table 5

<table>
<thead>
<tr>
<th>Model</th>
<th>Band</th>
<th>Receive Gain (dB)</th>
<th>Noise Figure (dB)</th>
<th>Image Rejection (dB)</th>
<th>Output Power (W)</th>
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</thead>
<tbody>
<tr>
<td>Down East 144-28HP</td>
<td>2 meters</td>
<td>18</td>
<td>1.0</td>
<td>101</td>
<td>60</td>
</tr>
<tr>
<td>Down East L222-28HP</td>
<td>1 1/4 meters</td>
<td>17</td>
<td>0.8</td>
<td>103</td>
<td>25</td>
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<tr>
<td>Elecraft K144XV*</td>
<td>2 meters</td>
<td>25</td>
<td>1.0</td>
<td>106</td>
<td>10</td>
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<tr>
<td>Elecraft XV144</td>
<td>2 meters</td>
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<td>1.0</td>
<td>70</td>
<td>20</td>
</tr>
<tr>
<td>Kuhne-Electronics MKU</td>
<td>10 GHz</td>
<td>20</td>
<td>1.2</td>
<td>not measured</td>
<td>3</td>
</tr>
<tr>
<td>SSB Electronic LT2S MkII</td>
<td>2 meters</td>
<td>21</td>
<td>1.0</td>
<td>not measured</td>
<td>20</td>
</tr>
</tbody>
</table>

*Internal option for K3 transceiver.

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Fig 28 — 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 29 — Inside view of the Kuhne Electronics (DB6NT) 10-GHz transverter.