Going QRP with an SDR: The FLEX-1500 HF+6 (Part 1)

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With the introduction of its FLEX-1500™ QRP HF+6 transceiver, FlexRadio Systems has really thrown down the performance gauntlet in the entry-level transceiver market. Because the FLEX-1500 is a pure software-defined radio (SDR) that requires a Windows™ PC running PowerSDR software to function, the $649 transceiver has no direct competition in its price class. All competing models are conventional radios with physical knobs, switches and controls (and most put out more RF power).

Buying decisions will likely hinge on the fundamental, functional differences between SDRs and traditional transceivers (plus RF power). If we consider only RF performance, the FLEX-1500 tops its price class and, amazingly, isn't too far below the performance mark set by the best-performing radios at any price.

This tiny software-defined radio is QRP on power and price, but QRO (increase) on performance and flexibility. But should it – or any SDR – be your next rig?

But before we explore the pluses and minuses of the FLEX-1500 in specific, and of SDRs in general, let's briefly look at today's entry-level transceivers and the features that define them.

Whether as a first radio or a backup rig, entry-level HF transceivers have to handle a wide variety of on-air tasks. These low-cost radios often look and feel a lot like their higher-priced siblings, and often benefit from the same technologies and design philosophies. Manufacturers are challenged to produce inexpensive models that are flexible, easy to use, and relatively complete, while offering as much RF performance as possible without making the radio so feature-rich and high-performance that it reduces sales of the company's higher-priced models.

Compared to years past, the functionality built into today's budget radios is truly impressive. With a minor exception or two, every entry-level transceiver has external 13.8-V dc power, dual VFOs, split-frequency capability, general-coverage receiver, optional crystal filters, memories, scanning, RIT (Receiver Incremental Tuning), IF (Intermediate Frequency) shift, noise blanker, QSK (full break-in keying) CW, built-in keyer, variable sidetone pitch/CW offset, CW on USB or LSB, direct frequency entry via keypad, speech processing, attenuator, preamp, ALC (Automatic Level Control) output for external amplifier, accessory ports, AF or IF DSP (Digital Signal Processing) and a PC control interface. Whew!

In addition to these features, FlexRadio's '1500 also has a Windows PC running PowerSDR software (not always a benefit) that provides an interface for all of the radio's displays, controls and settings, unlimited memories, unlimited DSP IF filter bandwidths for all modes, dual independent DSP noise blankers, highly-customizable DSP noise reduction, noise gate, a panadapter/band scope spectrum display, point and click tuning of signals on the spectrum display, 3-band and 10-band audio equalizers for receive and transmit, variable AGC attack settings, binaural stereo receive audio, an intelligent external interface and control bus (FlexWire), built-in connectors and switching logic for driving external transverters, a second receive antenna port, and a port for connecting a high-accuracy 10-MHz time base (only needed when driving external UHF or microwave transverters).

That's a lot of flexibility for a radio that weighs 1.4 pounds and is about the size of a two-inch-thick stack of QSL cards!

Because much of the radio's functionality is defined by software and firmware, new features and improved functionality can be regularly "added" to the radio. SDRs evolve, while conventional radios typically require hardware mods or fixes that are rarely, if ever, practical. (Some high-end radios enjoy software and firmware updates to their digital subsystems, but on a more limited basis.)

Simply listing every feature and spec of the '1500 would consume all of my allotted review space, but you can find plenty of info in Sidebar 1 and a more complete listing at **www.flex-radio.com/Products.aspx?topic=SDR_Feature_Matrix**. At this point it's easier to list the features that you won't find on the FLEX-1500 or in the radio's box on first opening.

You won't find a 100-Watt power amplifier (5-Watt maximum output), VOX (Voice Operated Transmitter), a built-in antenna tuner, a power supply, a microphone or a speaker. High-speed, butter-smooth full break-in keying may also be missing, but the verdict will have to wait until Part 2 of this review (June 2011 issue of *MT*).

Considering the radio's nature and price class, none of the "missing" items is a real shocker. Designed for QRPers, VHF/UHF and microwave enthusiasts who use the unique features of the '1500 to drive stacks of external transverters, and "toe dippers" who want an affordable introduction to SDR technology, the radio was carefully packaged to maximize the SDR user experience while keeping costs down.

I was initially surprised that a hand microphone wasn't included. I didn't have a modern Yaesu mic in my shack (works with the '1500), so I resurrected an old Shure desk mic from my junkbox and made an RJ-45 (LAN jack) plug according to the diagram in the user manual. It worked just fine, and the radio's extensive set of transmit audio enhancement tools (multiband EQ, noise gate, compressor, etc) made it sound better than ever.

The "missing speaker" really wasn't. The FLEX-1500 requires a stereo headset or speakers because it has many features that leverage two-channel audio (binaural filtering and audio processing, independent sideband reception, and more). Until I used these on the air I had no idea what I had been missing.

I can cover only a few aspects of the FLEX-1500 and its operation in this review, so let's get right to the biggie: the FLEX-1500 is a pure software-defined radio, a total black box with no VFO knobs, no front-panel frequency display, no front-panel nothin'. SDRs offer amazing RF performance and features that are impractical or impossible with conventional radios, but because SDRs require a computer and special software to function in any way, and because all of the controls are "soft," the ergonomics can make or break the overall experience.

Love it or hate it, SDR technology likely represents the future of all amateur radio hardware, save for purposefully designed "retro radios" or nostalgically home-brewed hardware. Only recently incorporated into ham radio gear, SDRs are used in billions of cell phones made over the past 15 years, and they're not going away any time soon.

❖ SDR Technology – It's Dynamic!

Conventional superhet receivers convert incoming signals to one or more intermediate frequencies before "detecting" and "demodulating" them by converting them to audio. This requires a carefully orchestrated and optimized sequence of filters, mixers, oscillators and amplifiers (at RF and AF). Careful gain distribution and interstage impedance matching is required to obtain the best performance. Critical functions such as AGC and IF/AF filtering are performed by mature analog circuits or in conjunction with newer IF or AF digital signal processing.

Various conversion schemes place the IF at higher or lower frequencies, or incorporate multiple IF conversions to provide for cascaded filters, increased image rejection, smoother gain and AGC control, etc. To achieve high dynamic range performance – the ability to receive weak desired signals in the presence of nearby strong unwanted signals – requires two or more cascaded IF filters (called roofing filters in some designs), often augmented with DSP. This approach can offer excellent performance, but it's quite expensive.

After a conventional RF front end (bandpass filters, RF amplifier and a first mixer), SDRs replace typical downstream hardware (mixers, amplifiers, filters, AGC, detectors, etc.) with DSP hardware and PC (or embedded) software. Instead of converting incoming RF signals to an intermediate frequency of 455 kHz or 9 MHz, an SDR converts the RF immediately to "baseband" (dc to 20 kHz), where it's digitized and processed by software and DSP. The functions that are traditionally handled by analog circuits and filters are almost completely handled in the digital domain. This makes SDRs sophisticated direct-conversion receivers.

The differences in conversion schemes and filtering methods highlight a key SDR advantage: dynamic range. Even with careful design and cascaded IF filters, conventional superhets offer excellent dynamic range at moderate to wide signal spacings, but performance falls off dramatically when offending signals are nearby. Crystal filters work well if unwanted signals are, say, 50 kHz away from the weak signals you're receiving. But if the unwanted signals are 5 kHz or 0.5 kHz away, the selectivity of traditional analog designs can't keep nearby unwanted signals from triggering the receiver's AGC and causing other undesirable downstream effects.

That's why the dynamic range of conventional superhet receivers is almost always specified at wide signal spacings where these radios can offer 80 to 100+ dB of usable dynamic range. If tested at spacings of 1, 2 or 5 kHz, however, their dynamic ranges often fall to 50 to 80 dB – far worse than the published specifications would suggest. Many conventional (and expensive) radios crumble at close signal spacings, and entry-level units are even worse.

SDRs have the opposite problem. After a single RF conversion to baseband, signals are digitized and processed in the digital domain. For all practical purposes, the dynamic range of the radio's DSP hardware sets the dynamic range for the receiver at all signal spacings. The FLEX-1500 has a specified dynamic range that's "in the 80s," with measured results as high as 88 dB – whether the unwanted signals are 0.1, 1, 2, 5 or 50-kHz away. The implications of this feature of SDR architecture are staggering.

Let's say that a typical conventional radio (that might cost five times as much) can offer a 100-dB dynamic range at a 50-kHz signal spacing. So far, so good. That clearly tops the '1500's performance benchmark. As signal spacings get closer and closer, however, the little FlexRadio holds steady with its constant 88-dB dynamic range as its expensive conventional counterpart starts to collapse. Under

TABLE 1: FLEX-1500 MANUFACTURER SPECIFICATIONS

Receiver Frequency Range	100 kHz - 54 MHz (operation below 480 kHz may require customer-provided pre-selectors or external filters for best performance)
Transmitter Frequency Range	160m - 6m (amateur frequencies only on main antenna port); continuous transmit coverage on low-power transverter output port only
Emission Modes	J3E (USB, LSB), A1A (CW), F3E (FM), A3E (AM, AM-synchronous), F1B (RTTY), F1D (data), F2D (data), DRM (Digital Radio Mondiale, requires the purchase of external third party software).
Frequency Steps	1 Hz minimum
Antenna Impedance	50 Ohms, unbalanced
Frequency Stability	+/- 2.5 ppm (adjustable in PowerSDR to sub-0.1 ppm accuracy)
Audio In	Unbalanced microphone (front panel), unbalanced line input (FlexWire, rear panel)
Audio Out	Headphone out, front panel (stereo only); unbalanced line output (FlexWire, rear panel)
Recommended Headphones	40 mW sensitivity, 8 ohms or higher
Power Consumption	400 mA receive, 2 A transmit (peak)
Supply Voltage	13.8 V dc +/- 10%
Dimensions (WHD)	Approximately 4 x 2 x 6 inches
Weight	22 oz (1.4 lbs)
Receiver Circuit Type	Direct-conversion, low IF
Intermediate Frequency	Software selectable from dc to 20 kHz
MDS	-138 dBm max @ 50-MHz.
Selectivity (-6/-60 dB)	500 Hz CW, 1.28:1 shape factor; 2.6 kHz SSB, 1.06:1 shape factor (filter performance determined by PowerSDR @ 48 ksps)
Image Rejection	70 to 100 dB, 160m-6m amateur bands (PowerSDR has a self-training image-rejection program)
Transmitter Power Output	0.05 - 5 watts (main RF port), 1.0 mW/0 dBm (transverter IF output port only)
Emission Modes	J3E (USB, LSB), A1A (CWL, CWU), F3E (FM narrow), A3E (AM and DSB-SC, double-sideband with suppressed carrier), DIGITAL
Harmonic Radiation	Better than -50 dB (160-10m amateur bands); better than -60 dB (6m amateur band)
SSB Carrier Suppression	At least 55 dB below peak output
Undesired Sideband Suppression	At least 55 dB below peak output
Audio Response (SSB)	Flat response 70 Hz to 20 kHz, 3-band or 10-band software EQ
3rd Order IMD	Better than 28 dB below PEP at 14.2 MHz, 5 W PEP
Microphone Impedance	600 Ohms (200 to 10 k Ohms)

In addition to the usual dc input and antenna output ports, the back side of the FLEX-1500 features some real rarities: transverter ports and an input for a high-accuracy 10-MHz frequency reference.

typical contest conditions, where powerhouse signals may be only 1 kHz away, the FLEX-1500 is now crushing the competition.

A quick look at Sherwood Engineering's receiver test data "scoreboard" at **www.sherweng.com/table.html**, shows that the $649 FLEX-1500, with its measured 88-dB dynamic range at 2-kHz signal spacing, is in the Top 10 of all radios tested at any price (the list is sorted on this category). It's almost ridiculous!

Although the Sherwood list is sorted for close-in dynamic range only, and many factors can determine a radio's ultimate performance and usability, the '1500's perch near the top of that list puts it rarefied company. A handful of more expensive radios outperform it, but the list of expensive radios it tops at 2-kHz signal spacing is also impressive (one radio costs nearly 18 times more than the FLEX-1500)!

Another look at the list reveals that, other than the Perseus RX-only SDR and the FLEX-3000™ and FLEX-5000™ SDRs (both siblings of the FLEX-1500), all of the others radios ranked above the FLEX-1500 are hybrids that combine down-conversion superhets with roofing filters and software-defined IF/AF subsystems. And they all cost thousands of dollars more.

❖ PC Perspectives

As mentioned, a Windows PC running PowerSDR is required for any and all functions. That's not always convenient, but it does provide for another powerful SDR feature: a band scope spectrum display that shows the strength and location of signals up and down the band in real time (in addition to the signal that you're tuning).

This feature is so powerful that I'm now reluctant to be without it. Many SDR operators feel the same way. Being able to *see* a signal, click on it with the mouse and have it perfectly tuned in is simply fantastic. It's a real game-changer, a huge step forward in the evolution of practical amateur radio technology.

Being the baby of the FlexRadio Family, the band scope on the '1500 spans 48 kHz of received spectrum – more than enough to be very useful. More expensive models cover a wider displayed spectrum, but that fact alone doesn't seem sufficient to warrant an upgrade.

Unlike the FLEX-3000 and the FLEX-5000, which use Firewire technology to connect the PC to the radio, the FLEX-1500 uses USB. FlexRadio engineers chose USB because it was universally available and less expensive than Firewire, but I think they might reconsider if they had to do it over again. USB is great for copying data files between hard drives and for many other non-critical tasks. But when it comes to synchronizing time-sensitive operations in real time on either end of the connection, USB can be a real pain.

FlexRadio engineers and early FLEX-1500 purchasers went through a rough patch for the better part of a year while the kinks were worked out. Thankfully, the latest version of PowerSDR, 2.0.19 RC1, although still technically "in beta," seems to be just what the doctor ordered. I will report my experiences with it in detail in Part 2, at which time the final stable release of version 2.1 may even be available.

After plenty of nail biting and teeth gnashing, FlexRadio engineers discovered that the USB timing issues were mostly dependent on a PC's USB chipset and its USB implementation, and not its operating system. Surprisingly, the newest, most powerful PCs often had the most problems. Beyond the fact that several companies manufacture chip-level parts that add USB capabilities to PC motherboards and add-on cards, specific implementations offload more or less USB processing to the PC's main CPU instead of handling it "in hardware" in the USB chips themselves.

Some USB designers thought that modern, fast PCs could handle plenty of USB housekeeping at the CPU level, allowing for inexpensive, less-capable USB chipsets. This works for simple file transfers, but when it comes to syncing two simultaneous data streams between PowerSDR and the FLEX-1500, problems ensued.

The fix involved software tweaks and the addition of adjustable buffers that allow users to precisely tune PowerSDR to their PC's specific USB hardware. A slider control in one of the many software setup menus makes the adjustment possible. Future versions of PowerSDR may configure these settings automatically.

Now that the USB issues have been largely solved, PowerSDR should be fine on any reasonably powerful PC running Windows XP, Vista or Windows 7. PC's with better USB hardware can run slower CPUs, and vice-versa. Tiny netbooks such as Toshiba's NB-205 (known to have good USB hardware) can run PowerSDR nicely, while some powerhouse i7-class PCs with junky USB chipsets need a lot more of their CPU power to reach the same efficiency.

PowerSDR 2.x is rated for use on 32-bit and 64-bit versions of XP, Vista and Windows 7, although as a veteran PC tech, I strongly advise against using Vista for anything beyond simple web browsing. Friends don't let friends run Vista!

Check the FlexRadio Knowledge Center for up-to-date hardware recommendations. I ran PowerSDR in 32-bit Windows 7 (a 3-GHz dual-core PC with 4 GB of RAM) and in 32-bit XP (an older machine with a 2-GHz single-core CPU and 1 GB RAM). Both worked well, but the CPU utilization on the older PC sometimes spiked to 100% if I was running logging, PSK or web software at the same time. The faster PC was "like butter" no matter what.

❖ Until Next Month...

In Part 2, I will share my experiences installing, using and integrating the latest version of PowerSDR into my previously conventional station. I'll also cover hardware options and using the FLEX-1500 as a receiver (super easy), a transceiver (straightforward), and in conjunction with logging and digital-mode software (doable, but a bit tricky).

In the meantime, feel free to spend some time at **www.flex-radio.com** perusing the photos, specs, articles and user forums. If you're interested in the FLEX-1500 – or SDR technology in general – the web site is a real education.