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FlexRadio Systems FLEX-6500 SDR Transceiver and Updated *SmartSDR for Windows* Software

The FLEX-6500 is a top-performance SDR with an emphasis on value.

Reviewed by Martin Ewing, AA6E
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It has been nearly 2 years since we reviewed the FlexRadio Systems FLEX-6300 and FLEX-6700 transceivers, and there have been big improvements in the 6000 series.¹ While the transceiver lineup remains the same, the Maestro control console has been added, and there has been important progress on the software side.² *SmartSDR* (SSDR) software (which includes components running in the radio and in your PC or other client device) has been through multiple important releases. New versions of *SSDR* adapted for the Maestro and for Apple iOS devices have been announced.

In this review, we look at the mid-level hardware offering in the Signature series, the FLEX-6500. In a nutshell, the '6500 delivers much of the performance of the high-end FLEX-6700 at a substantially lower cost. The biggest difference is that the '6500 receiver has only one analog-to-digital converter (ADC), while the '6700 has two independent ADCs.³ There are various other differences, so we have put the '6500 through the full ARRL Lab process. (Full disclosure: I own and have been using a FLEX-6500 as my



primary home station for more than a year.)

Progress through software enhancements is to be expected with SDR. It's great news for users, because you get a lot of mileage out of a single hardware purchase. But as we observed in 2015, the pace of change is a challenge for us humble reviewers, because a new software update will often come out before the latest review can be published. We count about nine software releases over the past 19 months, comprising around 700 change items,

Bottom Line

The FLEX-6500 is a very capable SDR, with flexibility and performance to satisfy the needs of most HF/6-meter operators. Regular software updates add features and enhancements long after the initial purchase.

so development is still very active. For the very latest scoop, you should consult the online user guides and release notes.⁴

Hardware

Let's compare the FLEX-6500 with the other 6000-series models, starting with its bigger brother, the FLEX-6700.

As we said above, the receiver part of the '6500 is roughly half of a '6700, covering 100 kHz – 72 MHz. The transmitter side is nearly identical, providing 100 W on the 160 – 6 meter bands. Outside the US, you may also have a 4-meter (70 MHz) band for transmit.

The FLEX-6500 does not provide the direct 2-meter operation that the FLEX-6700 does. For bands above 6 or 4 meters, you will have to provide an appropriate transverter. The '6500's frequency standard is a temperature-compensated crystal oscillator specified at 0.5 ppm stability — a step down from the FLEX-6700's oven-stabilized oscillator (0.02 ppm), but it's fine for most ham work.

On the receiver side, the single ADC means that you can only use one receive antenna at a time, so you do not have the diversity receive option.

Key Measurements Summary

FlexRadio Systems FLEX-6500 SDR Transceiver



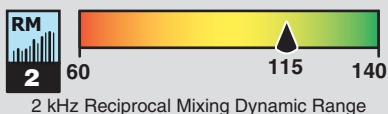
20 kHz Reciprocal Mixing Dynamic Range



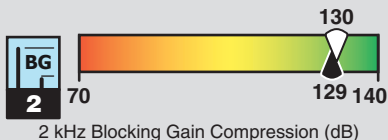
20 kHz Blocking Gain Compression (dB)



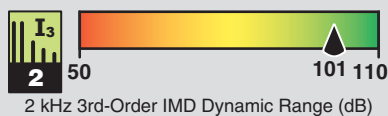
20 kHz 3rd-Order IMD Dynamic Range (dB)



2 kHz Reciprocal Mixing Dynamic Range



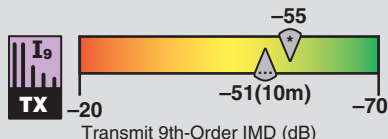
2 kHz Blocking Gain Compression (dB)



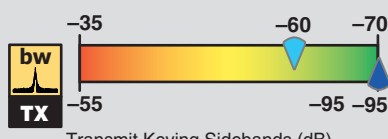
2 kHz 3rd-Order IMD Dynamic Range (dB)



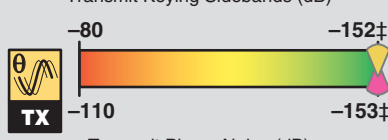
Transmit 3rd-Order IMD (dB)



Transmit 9th-Order IMD (dB)



Transmit Keying Sidebands (dB)



Transmit Phase Noise (dB)

PR114

Key:



Note: Measurements with receiver preamps off.
‡ off scale

Table 1
FlexRadio FLEX-6500, Firmware v1.9.7,
serial number 2016-5312-6500-6128

Manufacturer's Specifications

Frequency coverage: Receive, 0.03 – 72 MHz; transmit, 160-, 80-, 60-, 40-, 30-, 20-, 17-, 15-, 12-, 10-, and 6-meter amateur bands.

Power requirement: Receive, 2 A typical; transmit, 23 A maximum at 13.8 V dc ±15%.

Modes of operation: SSB, CW, FM, RTTY, digital, AM, and synchronous AM.

Receiver

CW sensitivity: MDS in 500 Hz BW, preselector off, preamp 1/2/3: -121, -125, -136 dBm.

Noise figure: Not specified.

Spectral sensitivity: Not specified.

AM sensitivity: Not specified.

FM sensitivity: Not specified.

Blocking gain compression dynamic range: Not specified.

Reciprocal mixing dynamic range: Not specified.

ARRL Lab Two-Tone IMD Testing (400 Hz bandwidth)

Band/Preamp	Spacing	Measured IMD Level	Measured Input Level	IMD DR
3.5 MHz/Off	20 kHz	-120 dBm	-20 dBm	100 dB
		-97 dBm	-6 dBm	
14 MHz/Off	20 kHz	-120 dBm	-17 dBm	103 dB
		-97 dBm	0 dBm	
		0 dBm	-97 dBm	
14 MHz/1	20 kHz	-126 dBm	-26 dBm	100 dB
		-97 dBm	-8 dBm	
14 MHz/2	20 kHz	-136 dBm	-36 dBm	100 dB
		-97 dBm	-16 dBm	
14 MHz/Off	5 kHz	-120 dBm	-18 dBm	102 dB
		-97 dBm	0 dBm	
		0 dBm	-97 dBm	
14 MHz/Off	2 kHz	-120 dBm	-19 dBm	101 dB
		-97 dBm	-3 dBm	
		0 dBm	-97 dBm	

Measured in the ARRL Lab

Receive, 0.100 – 74 MHz; transmit, as specified.

At 13.8 V dc: Transmit, 17 A (typical), 20 A (maximum). Receive, as specified. Off, 54 mA.

As specified.

Receiver Dynamic Testing

Noise floor (MDS), 400 Hz BW:

Preamp	Off (dBm)	1 (dBm)	2 (dBm)
0.137 MHz	-117	-119	-125
0.475 MHz	-121	-126	-133
1.0 MHz	-121	-127	-136
3.5 MHz	-120	-126	-136
14 MHz	-120	-126	-136
50 MHz	-120	-126	-136
70 MHz	-116	-123	-133

Preamp off/1/2, 14 and 50 MHz: 27/21/11 dB.

Preamp off/1/2: -125/-132/-141 dBm.

10 dB (S+N)/N, 1 kHz, 30% modulation, 6 kHz BW:

Preamp	Off (μV)	1 (μV)	2 (μV)
1.0 MHz	6.02	3.02	1.00
3.8 MHz	8.60	3.59	1.00
29.0 MHz	8.03	3.89	1.19
50.4 MHz	8.80	4.12	1.38

For 12 dB SINAD, 16 kHz BW:

Preamp	Off (μV)	1 (μV)	2 (μV)
29 MHz	2.57	1.26	0.40
52 MHz	2.66	1.33	0.44
70 MHz	3.48	1.78	0.59

Blocking gain compression dynamic range, 400 Hz BW:

	20 kHz offset Preamp off/1/2	5/2 kHz offset Preamp off
3.5 MHz	130/129/129 dB	130/130 dB
14 MHz	130/130/129 dB	130/129 dB
50 MHz	130/129/129 dB	130/129 dB

14 MHz, 20/5/2 kHz offset: 122/116/115 dB

Manufacturer's Specifications

Measured in the ARRL Lab

Band/Preamp	Spacing	Measured IMD Level	Measured Input Level	IMD DR
50 MHz/Off	20 kHz	-120 dBm -97 dBm	-20 dBm 0 dBm	100 dB
50 MHz/2	20 kHz	-136 dBm -97 dBm	-36 dBm -16 dBm	100 dB

Second-order intercept point: Not specified.

DSP noise reduction: Not specified.

Notch filter depth: Not specified.

S-meter sensitivity: Not specified.

Receive processing delay time: Not specified.

IF/audio response: Not specified.

Image rejection: >100 dB.

Transmitter

Power output: CW/SSB/FSK/FM, 1 – 100 W nominal. AM, 25 W nominal at 13.8 V dc.

Spurious-signal and harmonic suppression:
HF, -60 dBc; 50 MHz, -70 dBc.

SSB carrier suppression: <80 dB.

Third-order intermodulation distortion (IMD): Not specified.

Transmit bandwidth: Default 100 – 2900 Hz (variable 50 Hz – 10 kHz).

CW keyer speed range: Not specified.

CW keying characteristics: Not specified.

Transmit-receive turnaround time (PTT release to 50% audio output): Not specified.

Receive-transmit turnaround time (tx delay): Not specified.

Composite transmitted noise: Not specified.

Size (height, width, depth, including protrusions): 4 × 13 × 12 inches. Weight: 13 pounds.

Price: \$4,299 including FHM-1 hand microphone. Available options: Maestro control console, \$1,199. FlexControl USB tuning knob, \$99.95; GPS Disciplined Oscillator \$699; Handle Kit \$75; Rack Mount Kit \$99.

Receiver tests performed at 400 Hz bandwidth, the default for CW mode. There is no significant difference in sensitivity or dynamic ranges between 400 and 500 Hz. Second-order intercept points were determined using S-5 reference.

*Default values; bandwidth is adjustable via DSP and latency settings. See sidebar.

**Power output is 15 W lower at minimum operating voltage.

Preamp off/1/2: 14 MHz, +77/+77/+77 dBm;
21 MHz, +75/+73/+73 dBm;
50 MHz, +75/+75/+75 dBm;

Not measured. See sidebar.

24 dB (auto notch filter),
>60 dB (tunable notch filter).

S-9 signal, preamp off/1/2:
14 MHz, 58.8/58.8/58.8 μ V;
50 MHz, 67.8/67.8/67.8 μ V.

At transceiver headphone jack, 100 ms.

Range at -6 dB points:*
CW (400 Hz): 400 – 800 Hz (400 Hz);
Equivalent Rectangular BW: 397 Hz;
USB (2.4 kHz): 101 – 2507 Hz (2406 Hz);
LSB (2.4 kHz): 101 – 2507 Hz (2406 Hz);
AM (6 kHz): 23 – 3027 Hz (6004 Hz).

92 dB.

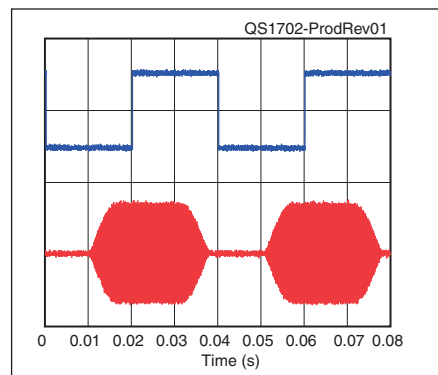


Figure 1 — CW keying waveform for the FLEX-6500 showing the first two dits using external keying. Equivalent keying speed is 60 WPM. The upper trace is the actual key closure; the lower trace is the RF envelope. (Note that the first key closure starts at the left edge of the figure.) Horizontal divisions are 10 ms. The transceiver was being operated at 100 W output on the 14 MHz band.

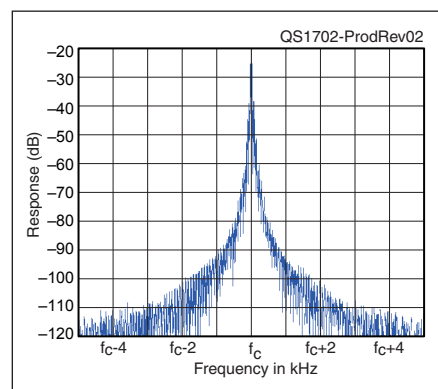


Figure 2 — Spectral display of the FLEX-6500 transmitter during keying sideband testing. Equivalent keying speed is 60 WPM using external keying. Spectrum analyzer resolution bandwidth is 10 Hz, and the sweep time is 30 seconds. The transmitter was being operated at 100 W PEP output on the 14 MHz band, and this plot shows the transmitter output \pm 5 kHz from the carrier. The reference level is 0 dBc, and the vertical scale is 10 dB/division.

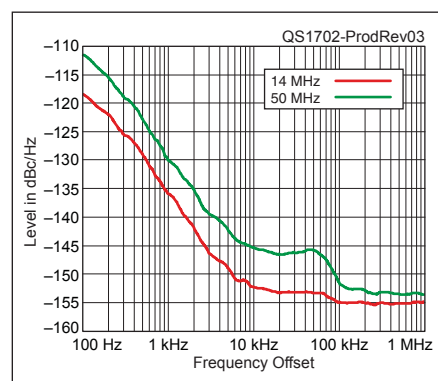


Figure 3 — Spectral display of the FLEX-6500 transmitter output during phase noise testing. Power output is 100 W on the 14 MHz band (red trace) and 50 MHz band (green trace). The carrier, off the left edge of the plot, is not shown. This plot shows composite transmitted noise 100 Hz to 1 MHz from the carrier. The reference level is -110 dBc/Hz, and the vertical scale is 5 dB per division.

Equipment Reviewed

FLEX-6500 SN 2016-5312-6500-6128
SmartSDR for Windows, version 1.9.7
and 1.9.13

But if you are working on, say, an 80-meter dipole, you *can* monitor activity on other bands, although with less sensitivity because the antenna may not be resonant. You will also have to use the same preamp or attenuator settings on all bands, and you will lose the benefits of the band-specific

preselectors, which are disabled when you are listening on multiple bands. Nevertheless, you can run four separate panadapters and four separate “slices” (audio/data channels) spread across the full 30 kHz – 72 MHz input range (see Figure 4). This can be very helpful if you need to monitor activity across bands or band segments.

There are a couple of other limitations of the FLEX-6500 compared with the '6700. The '6500 can't directly support SO2R contesting the way the '6700 can. The '6500's top frequency resolution is about a quarter of the

'6700's. That can limit your spectral sensitivity in certain situations — detecting very weak VHF beacons, for example.

Now we compare the FLEX-6500 with its little brother, the FLEX-6300. The '6500's four panadapters/slices are double the '6300's. Each '6500 panadapter can display up to 14 MHz of bandwidth, compared with 7 MHz on the '6300. The FLEX-6500 gives you receiver preselector filters that help reject strong out-of-band interference, while the '6300 ADC is unfiltered. The FLEX-6500 has a built-in antenna tuner, but that is an optional add-on for the '6300. The '6500, but not the '6300, will accept FlexRadio's GPS disciplined oscillator option, which can give you higher accuracy and stability along with a 10 MHz reference output. The FLEX-6500 provides for more flexible connection of external microphones, amplifiers, and transmitters.

For the most part, the FLEX-6500 sailed through our Lab test process, as Bob Allison, WB1GCM, explains in the sidebar, “Lab Notes: FlexRadio Systems FLEX-6500.”

Software

In my first review of the FLEX 6000 series (see Note 1), I reported our experience with version 1.3.8 of *SmartSDR for Windows (SSDR)*. That version had a heavy CPU and graphics load that was a problem, especially when you requested the maximum number of panadapters and slice receivers and a full screen display with fast updates. Current *SSDR* versions need much less computer power.

I tried operating the FLEX-6500 with a relatively modest computer, an HP Compaq using a dual-core Intel E2160 CPU running at 1.8 GHz, along with 2 GB RAM and *Windows 7* and on-board Q963 Express graphics. Compared with faster systems, the graphical updates were a bit jerky, but

Lab Notes: FlexRadio Systems FLEX-6500

By Bob Allison, WB1GCM
Assistant ARRL Laboratory Manager

There were no significant issues while testing the FLEX-6500. On the receive side, the reciprocal mixing and blocking dynamic ranges are excellent. Initial laboratory measurements of the two-tone third-order IMD dynamic range indicated a respectable 94 dB at 2 kHz spacing at 14 MHz. Even so, FlexRadio informed the Lab that this was not up to their standards. FlexRadio determined that an analog gain component was out of spec, replaced one resistor to move the gain back into tolerance, and that brought the two-tone, third-order IMD dynamic range at 2 kHz spacing up to the expected 101 dB. Under real-world conditions, this problem would not be apparent unless perhaps you were operating in rather adverse conditions with very strong nearby stations. Of the three dynamic ranges, the lowest is 101 dB — top level performance, indeed.

The FLEX-6000 series has selectable receive filter settings, consisting of sliders on a menu screen to adjust the filter shape. Each slider (one each for SSB, CW, and digital) has a range from “low latency” to “sharp filters.” This adjustment has a direct effect on the transmit-receive turnaround duration times, as shown in Table 1. It is interesting to see that more processing time is required for sharp filter settings. These adjustments are of particular interest to high-speed CW operators. Note that the filter shape adjustment has no effect on the receiver processing delay time (signal at antenna versus signal heard at speaker).

I was not able to measure the DSP noise reduction. When a single signal is present (as is the case during Lab testing), with added noise from a noise generator both the signal and the average noise level drop equally with the noise reduction feature on. However, when listening on the air during noisy conditions, I can hear the signal better with NR on. It's just something that we cannot quantify in the Lab.

The transmitter also performs well. In particular, it exhibits low transmit phase noise and narrow keying sidebands. The transmit IMD is reasonably low as well. Note that, starting with this review, we have changed the presentation of the phase noise plot (see Figure 3). We have adjusted the Y axis to show the range of –110 to –160 dBc/Hz for a more detailed view of the phase noise measurements and easier interpretation. The measurement technique is unchanged.

An interesting feature worth noting is the adjustable transmit bandwidth, with a maximum range of less than 100 Hz to 10 kHz. Users may wish to experiment with wider transmit bandwidths (ESSB), but if the band is crowded, limit the transmit bandwidth to less than 3 kHz in consideration of other users. I set the low cut frequency to 300 Hz, and the high cut to 3 kHz. Testing showed the –6 dB transmit bandwidth points to be very close to filter cutoff frequency software settings.

Finally, the FLEX-6500 draws current when powered off — 54 mA. Keep this in mind if you use a battery as a power source.

I judge the HP computer would be usable, though not my first choice.

With my somewhat faster Toshiba L654D (described in the earlier review) running *Windows 10*, operations were much smoother. My larger Core i7 desktop machine with a GT-640 graphics card is now clearly overkill for *SSDR*. Given these results, I would expect that typical dual-core desktop computers (and many laptops) purchased in the last few years would be adequate for *FLEX SSDR*.

Many other improvements in *SSDR* have come along since version 1.3.8. They include support of the new Maestro and iOS clients mentioned above, support for remote operation over your local area network (LAN), FM, full-duplex operation, D-STAR via a ThumbDV USB module and matching waveform software, and more.⁵

Operating

The FLEX-6500 has proven to be easy to set up and operate. Electrically, the connections are similar to what we would expect for any modern transceiver, and Figure 5 shows the rear panel. I added an Elecraft XV-144 transverter and my old Heath SB-220 amplifier with little fuss. The '6500's multiple transmit-enable outputs allow me to key the amp or transverter only when needed. I attached my Heil/TEN-TEC microphone to the front panel jack, after some work to rewire the mic cable for Flex's eight-pin Foster connector.

On-air audio reports have been excellent, after adjusting the Flex-6500's eight-channel transmit equalizer. (A separate eight-channel equalizer is available for receive.) It would be very handy if *SSDR* provided audio diagnostics to help you set up your equalizer and levels, but you have to equalize the old-fashioned way — recording and listening to your signal or working with a friend. Flex's excellent

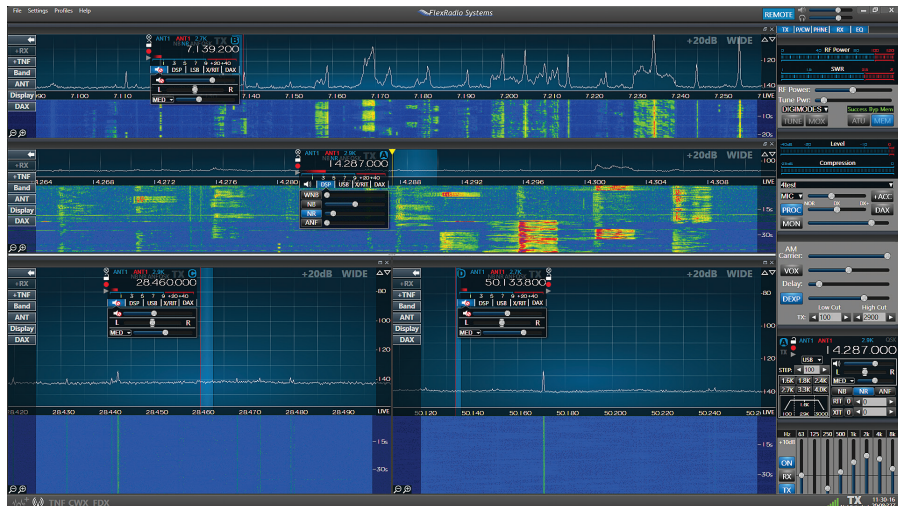


Figure 4 — *SSDR for Windows* controlling four panadapters/slices of the FlexRadio FLEX-6500, monitoring the 40-, 20-, 10-, and 6-meter bands.



Figure 5 — The FLEX-6500 rear panel. Connections include two antenna jacks, transverter, receive antenna, powered speaker, 10 MHz reference input, three TR relay outputs for controlling power amplifiers and other external devices, balanced audio input, amplifier ALC, PTT, transmit interlock, Ethernet, and USB ports for SmartSDR functions. The 15-pin ACCESSORY jack has connections for audio line in/out, CW and FSK keying, PTT, and other features.

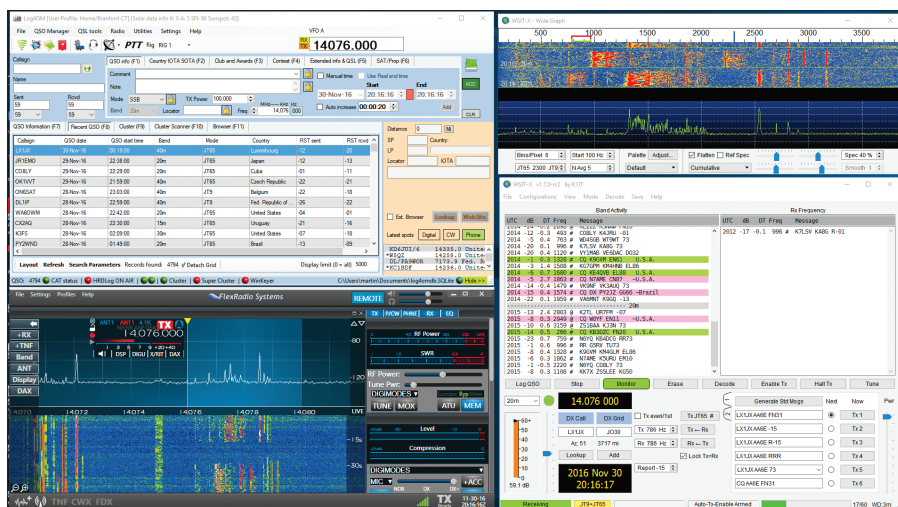


Figure 6 — *SSDR for Windows* and the FLEX-6500 operating JT65 mode with *WSJT-X* software. *Log4OM* handles QSO logging functions.

FLEX-6500: A Contester's Impressions

By Chris Tate, N6WM
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As a serious contester, I am constantly on the lookout for products and strategies that can give me an edge. For professional race car drivers, there is the constant struggle to tweak aerodynamics and squeeze more horsepower. But every now and then, something innovative happens that changes the competition. Serious Amateur Radio contesters do the same with our stations.

Panadapters have been around for some time, but the FLEX-6000 series combines a visual display with a direct sampling architecture and the computing power to manage the architecture included within the rig. The FLEX radios also offer a choice of different methods to control the SDR over a local network (*SmartSDR for Windows* with the FlexControl tuning knob, the Maestro interface, and third-party applications developed using the FlexAPI, such as the excellent K6TU control app for iOS).

When connected to a typical triband Yagi antenna, the FLEX-6500 gives me a view of multiple bands at the same time (the contester's playing field). The ability to open up four receiver "slices" gives me an awareness of not just one, but several bands simultaneously, should the need arise. Never again will I miss that 15-minute, 10-meter opening and critical multipliers lost while I was busy running stations on 20. And if 10 meters does open suddenly, I am there with a single mouse click to pounce on stations before the rest of the crowd arrives. I can also watch in real time as packs of competitors switch bands as part of their operating strategies. We could do this before, but it took multiple radios and antennas with

(in some cases) panadapter add-ons. Now we can do it with expanded capability from a single transceiver, interface, and triband antenna.

Unlike its FLEX-6700 big brother, which is ready for SO2R (single-operator, two-radio) operation out of the box, the FLEX-6500 has a single spectral capture unit, and so it is not capable of full duplex operation on multiple bands simultaneously (transmitting on one band while continually listening on another). But the FLEX-6500 remains capable of viewing multiple bands during receive, giving me a great deal of the multi-radio benefit and band awareness. Although I have not personally tried this, you could attach a separate, properly isolated antenna to the RXA port with full duplex enabled for continuous band awareness or to run a CW skimmer or similar program on a separate band.

The advantage here is more the equivalent to a visually enhanced SO2V (single-operator, two-VFO) capability. If you set up your logging software in an SO2R configuration using the OTSRP protocol, you almost have full SO2R capabilities (instant switching between two bands and VFO tracking via the logger), minus the full duplex.

It's always been a challenge to find a clear frequency on the crowded, contest congested bands. With the FLEX-6500 display in *SmartSDR* or *Maestro*, this challenge has been reduced. The panafall and receiver sensitivity, and ability to scale down or up, instantly allows me to see a clear run frequency opportunity and gives me precious time to work more stations.

My contest operating workflow has not changed that much, but it has been enhanced by the display capabilities and band awareness and other features stated above. Because this platform has been designed to interface with a number of the most popular contest logging packages, all the time I spent becoming comfortable with my logger on other platforms transferred right over.

My contest *setup* workflow, on the other hand, has been greatly simplified by the use of the virtual serial ports that can be set up on the fly — cable-free. The Digital Audio Exchange (DAX) allows me to interface my audio needs for SSB and RTTY, also cable-free. The internal Winkeyer emulation gives me the popular CW keyer functions, again completely free of cables and external devices. The "rat's nest" of cables in my shack is gone, reducing the opportunity for RFI, and the virtual replacements have simplified and reduced time needed for contest setup. I have reclaimed some of that desk space with more computer monitors (two or three, depending on the contest) to take advantage of my new band-aware visual tool.

Another advantage is that the FLEX-6000 series transceiver can be co-located outside of your shack (or you can co-locate yourself) without any compromise in display, functionality, or band awareness, so I can fully use the radio from anywhere.

The combination of all these things has sparked the excitement that I felt in my first contest. That rush and all of these new tools keeps me in the chair, and that will hopefully put me in the winner's circle for many contests to come.



N6WM operating a FLEX-6500 with *SmartSDR* and FlexControl from the 40-meter operating position at N6RO in heavy SSB contest conditions. There are two slices open, each on their own panafall instance, both on 40 meters in a modified OTSRP SO2R same-band configuration. That allows him to maintain a run frequency while simultaneously and visually enabling search and pounce opportunities up the band. Chris nearly broke the N6RO station record on 40 meters for this contest.

voice compression system (described in the earlier review), gives you the level of punch or fidelity that you need. A “downward expansion” option acts as a voice gate, suppressing background noise from your shack.

On the software side, there were few problems installing *SSDR* under either *Windows 7* or *Windows 10*. The most complicated issues had to do with setting up *WSJT-X* and *Fldigi* digimode software along with *Log4OM* logging software (see Figure 6). These required working with *SSDR*’s “CAT” component that manages software COM port connections. The digimode software required connections to Flex’s “DAX” audio channels. This setup was straightforward, at least if you have some experience managing COM ports and audio configuration under *Windows*. Overall, logging and digimode functions have integrated well with the FLEX-6500.

I have also been using the ’6500 with Flex’s Maestro control console, which can replace your *Windows* computer. The Maestro itself does not support CAT or DAX, but I have found that I can split the ’6500 control connections so that digimode and logging software on the *Windows* PC still work while Maestro controls the transceiver and

displays spectra. [As this review was going to press, FlexRadio released SmartSDR v1.10, which supports multiple CAT, BCD, and binary control of station devices from the USB ports on the back of the radio. This means that Maestro can set up and control those ports for local or remote operation without the need for a PC at the radio. A PC is still required for digital mode operation using DAX. — *Ed.*]

Summing Up

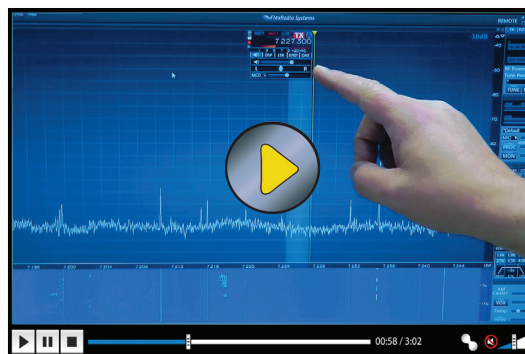
Overall, the FLEX-6500 is a very capable software-defined radio, with specs at or near the top of the range of amateur gear. It has the flexibility and performance to satisfy just about any HF/6-meter ham operator, and it is a

pleasure to operate. The *SSDR* operating software is still gaining new capabilities that should protect your hardware investment well into the future.

Manufacturer: FlexRadio Systems, 4616 W. Howard Ln. Suite 1-150, Austin, TX 78728; Tel. 512-535-4713; www.flexradio.com.

Notes

- ¹M. Ewing, AA6E, “FlexRadio Systems FLEX-6300 Transceiver, FLEX-6700 Transceiver, and *SmartSDR for Windows* Software,” Product Review, *QST*, Apr. 2015, pp. 47 – 58.
- ²M. Ewing, AA6E, “FlexRadio Systems Maestro Control Console,” Product Review, *QST*, Nov. 2016, pp. 10 – 14.
- ³FlexRadio uses the term “signal capture unit,” which comprises the ADC and associated circuitry.
- ⁴www.flexradio.com/support/downloads/nwdigitalradio.com/wp-content/uploads/2012/04/ThumbDV-A.pdf
- ⁵www.flexradio.com/support/downloads/nwdigitalradio.com/wp-content/uploads/2012/04/ThumbDV-A.pdf



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