By Bob Larkin, W7PUA

The DSP-10: An All-Mode 2-Meter Transceiver Using a DSP IF and PC-Controlled Front Panel

Part 3—This is it! It's about time to put your new transceiver on the air!

Before you press that mike button or key, you should become familiar with the operation of your new transceiver and what you can expect from it. I'll cover that this month along with some ideas I have about future expansion.

Operation

By simply attaching an antenna, speaker and microphone to the transceiver, you can operate 2-meter QRP. First, connect the transceiver's DB9 connector to a PC serial port you've chosen, then apply power to the transceiver and PC. Programs load first into the DSP, then into the PC. The default PC configuration screen (see Figure 13) is that of a 2-meter transceiver with a large frequency display and a help summary. For weak-signal work, an alternate display (see Figure 14) is available.

The frequency to which the transceiver is tuned is displayed on the PC's screen and changed by using the **F9** (down) and **F10** (up) keys. Used alone, these two keys tune the transceiver in 10-Hz steps. For faster tuning, press and hold the keyboard's **SHIFT** key in combination with the **F9** or **F10** key to tune in 100-Hz steps. Other modifier keys allow tuning in steps ranging from 1 Hz to 1 MHz. You'll likely find that using a PC keyboard to tune a radio takes some getting used to. That's because most of us are accustomed to turning a knob. But the simplicity of being able to go "up 20 kHz" in two keystrokes is great!

Function keys **F7** and **F8,** respectively, increase and decrease the audio gain in 2-dB steps. Pressing the **SHIFT** key modi-

PHOTOS BY THE AUTHOR

The transceiver's main board is visible with the DSP box removed. The RF circuitry lies along the right-hand side; the synthesizers are in the center.

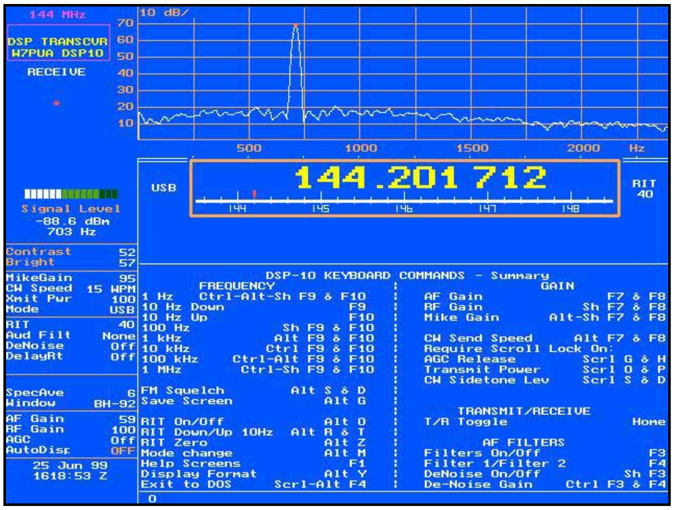

Figure 13—The default PC-configuration screen is that of a 2-meter transceiver with a large frequency display and a help summary.

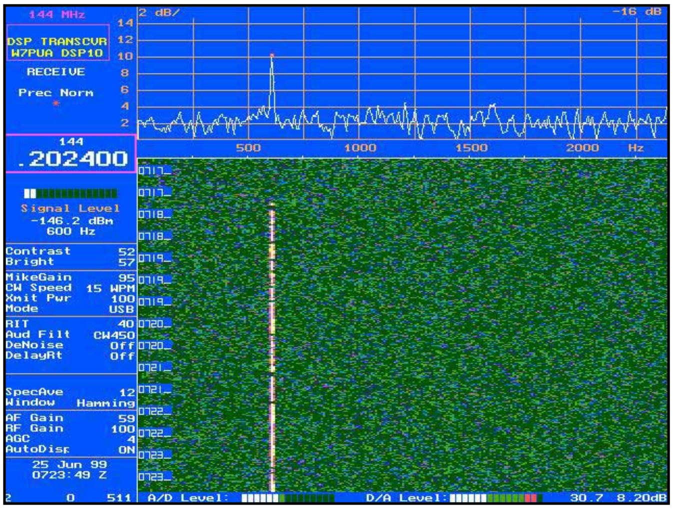

Figure 14—For weak-signal work, you can use the alternate PC-configuration screen shown here.

fies this function to adjust RF gain in 6-dB steps. Mode selection—USB, LSB, CW, or FM—is controlled by the **Alt-M** or **Alt-m** keypresses. Various other keys are used to control receiver functions such as RIT, CW filters and LMS denoise gain.

Signal strength is displayed in dBm (decibels relative to a milliwatt). When a transverter is used ahead of this transceiver, this readout is corrected to allow for the transverter's gain. A bar graph above the signal-level display acts as an S meter with 6-dB steps.

The maximum available transmitter output power is 20 mW. This is sufficient to drive any mixer used in a transverter. If your transverter is equipped with an attenuator for use with drive levels greater than 20 mW, you'll need to alter the attenuator-pad values to decrease the attenuation level. Unless you're a dedicated QRP operator, you'll *want* to add an external amplifier when operating this transceiver on 2 meters!

To transmit, push the mike button or press the PC's **Home** key. If there's a backlog of data coming from the DSP to the PC, there can be a delay (a fraction of a second) between pressing the mike's PTT switch and transmitting. Pressing the **Home** key, however, makes the changeover immediately. A relay sequencer, controlled by the PC's software, produces logic-level outputs for antenna-relay and power-amplifier control. For our simple example, we do not need this feature because we are not using an external amplifier. An on-screen display shows output power when operating SSB and deviation when using FM. You'll find that operating SSB or FM with this transceiver is quite similar to using a conventional multimode transceiver.

For CW operation, you have several keying options. A key jack mounted on the enclosure accepts a hand key. Alternatively, the PC keyboard's right-hand **Alt** key can function as a hand key. Finally, you can use the computer keyboard as a CW generator. Alphanumeric keys enter information into a buffer that is sent when in the transmit mode. During receive or transmit, data can be entered into the buffer. The buffer data is shown in a three-line display at the top of the screen. Prosigns such as **$\overline{\text{AR}}$** and **$\overline{\text{SK}}$** are sent by pressing the appropriate keys in combination with the **Alt** key. By enclosing a sequence of characters between pound signs (#), that character sequence can be sent repeatedly. As soon as the pound sign is encountered, the character sequence is repeated continuously until canceled by pressing the **@** key. Pressing the **Home** key switches the DSP-10 to transmit and starts the CW transmission. The next **Home** keypress toggles back to receive. CW speed is changed by using the **Alt-F7** (increase speed) and **Alt-F8** (decrease speed) keys.

When operating CW, the spectral display offers tuning information that is not otherwise available. One display line shows the current CW offset. A marker on the display identifies the frequency of the strongest signal in the passband; this can be used to set the operating frequency. The spectral display shows the entire audio spectrum, unrestricted by any narrowband filter that might be in use. In the voice modes (FM and SSB), the spectral display offers little new information except, perhaps, when on FM where repeater tone signals are easy to observe and identify.

One design goal of this transceiver was to remove operating-frequency ambiguities as much as possible. The CW mode is one area where this often can present problems. During transmit, the displayed frequency is the *actual* transmitted frequency. In receive, the displayed frequency is that required to produce an audio pitch equal to the CW offset. The CW offset is normally set to the center frequency of the audio filter, if one is used, but it can be set to any value. If RIT is in use, the transmit and receive frequencies can be separate, but the receive-frequency display will reflect this change. The sidetone sent to the speaker when the key is down is the same frequency as that of the CW offset.

If you want to use a transverter for, say, 1296 MHz, with the transceiver, there is provision to correct the display to show the actual transmitted frequency. The conversion frequency and other transverter information are obtained from a configuration file.

Band changing is accomplished from the keyboard using the **Ctrl-Alt** modifier. The key used is then the same as the letter or number used in the ARRL VHF-Contest band designators. For instance, 1296 MHz would be displayed if **Ctrl-Alt E** is pressed. This band changing is treated in the way usually referred to as a "VFO," meaning that if you switch to another band and then return to 1296, the transceiver is returned to the last 1296-MHz frequency used. If the transceiver is turned off, it is returned to the last frequency used when turned on again.

Presently there are no memories in the sense of fixed-frequency values. There are, however—in addition to the transverter bands—six VFOs dedicated to 2 meters that can include a mix of modes.

A number of seldom-used controls, such as the **CW Offset** discussed earlier, require use of the **Scroll Lock** key. This serves as an element of protection against inadvertent control changes. Another example is program termination: That requires simultaneous keypresses of **Scrl Lock-Alt-F4**.

To store the state of the transceiver at shutdown, the PC uses a configuration file (*UHFA.CFG*). This same file can be used to alter the transceiver's operational parameters. For instance, the calibration constant for the **Signal Level** display comes from this file. In order to have a known starting point, it is best to start with *no* configuration file. At shutdown, the program will write a file that contains the default parameters. Eventually you'll find it necessary to add more parameters such as transverter gains and conversion-oscillator frequencies, but not initially.

The PC's program will *not* run in a DOS window under *Windows 95/98*. This may be somewhat annoying for those whose computers always boot up running *Windows*. You must then quit *Windows* and elect to reboot to DOS. This situation affects only casual users of this program, because those running the transceiver-control program on a regular basis will not have loaded *Windows*.

Weak-Signal Displays

One of the driving forces behind this project was a desire to produce a good weak-signal transceiver for UHF and microwave frequencies. Spectral displays useful for such purposes are included as operator-controlled options. As shown in Figure 14, a waterfall display[20] is available. The way in which the spectrum display is sliced into colors is fully controllable. Also variable is the amount of averaging before the display is updated. To allow off-line experiments with the weak-signal processing, the spectral data can be recorded in a file as it is gathered and saved to disk.

Performance

The obvious question regarding this transceiver is: "How well does it work?" For use as an IF for a UHF/microwave transverter, it is quite satisfactory. At my station, the transceiver has worked well as a 2-meter radio. However, my location is not subject to many strong local signals. As we'll see, the dynamic range of the receiver is probably the weakest point of this design. Early on, I realized that providing state-of-the-art dynamic range would add considerably to hardware complexity. This radio's design is intended to minimize hardware complexity wherever possible.

Now to the numbers. Table 2 shows the transceiver's measured performance. The receiver sensitivity is adequate for most general work; any transverter used ahead of the DSP-10 will dominate the overall noise figure. Gain added ahead of the transceiver is detrimental to dynamic range. If the transverter gain is more than 10 or 15 dB, reduce the RF gain of the DSP-10.

The input third-order intercept point is an issue when more than one strong signal is present in the passband. Two 500-µV signals will produce an intermodulation product of about 0.3 µV. This level of interference would certainly be a problem. However, most 2-meter operators do not encounter such signal levels. The image and IF rejections are very high, eliminating "birdie" problems.

Transmitter spurious outputs are better than current FCC requirements for a transceiver of this power level. If an amplifier is used with the transceiver, the LO signal at 19.665 MHz below the transmitter frequency is probably the one that you should watch for spectral-compliance problems. Presently, that signal level is –69 dB.

Using DSP to generate SSB produces results that are somewhat different from their analog counterparts. It is very easy to suppress the carrier and the opposite sideband. During transmit, however, there is a flat level of noise across the 3-kHz transmit band that is caused by A/D conversion. The total noise power is about 65 dB below peak output, so it should not be a problem on the air.

On CW, the noise level is lower than on SSB and comes from the DAC. This noise occupies roughly 5 to 8 kHz on either side of the transmitted carrier and is limited by the crystal filter.

Table 2
Measured Performance

General
Power requirements: 13.6 V, 0.72 A maximum in receive; 0.75 A maximum in transmit.
Operating voltage range: 10.6 to 16.0 V
Frequency coverage: 144-148 MHz

Receiver
Receiver noise floor, 450-Hz filter: –136.8 dBm
FM 20-dB quieting: 0.31 µV
Second-order intercept point (66- and 78-MHz inputs): +69 dBm
Third-order intercept point: –21 dBm
IF rejection (19.665 MHz): 127 dB
Image rejection (104 to 108 MHz): 125 dB
Audio power, each channel @ 13.6 V: 0.77 W into 4 Ω, 0.85 W into 8 Ω.
Audio power, each channel @ 11 V: 0.54 W into 4 Ω, 0.48 W into 8 Ω.
Audio response, SSB filter, –6 dB: 190 Hz to 3020 Hz.
Audio response, 450-Hz CW filter: 310 to 750 Hz.

Transmitter
Maximum output power (rated output is 20 mW), CW or FM: 40 mW
Harmonic suppression at full output: greater than 62 dB
Conversion oscillator feed-through (f_0 = 19.665 MHz): –69 dB
Third-order intermodulation, 700 and 1900 Hz tones, 20 mW peak power: –33 dB
Fifth-order intermodulation, 700 and 1900 Hz tones, 20 mW peak power: –42 dB
Carrier suppression: greater than 50 dB
Opposite sideband suppression: greater than 60 dB

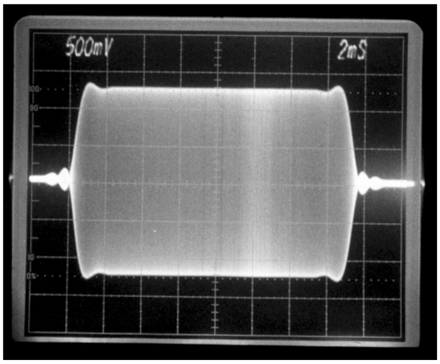

Figure 15—Keyed waveform of the transceiver in CW mode. The keying envelope has a distinctive ripple at the end of dots and dashes. This is a result of generating the CW signal as modulation of a carrier by a 500-Hz bandwidth-limited signal. This shaping essentially eliminates key clicks more than 500 Hz from the carrier

Figure 15 shows the transceiver's CW keying waveform. In spite of the rapid rise time of about one millisecond, key clicks are still concentrated within 500 Hz of the carrier frequency. Ripple can be seen on the waveform at both turn-on and turn-off. This rather ideal keying characteristic results from the band-limited keying waveform that amplitude modulates the carrier to produce CW. As you might expect, the on-the-air sound is crisp without audible key clicks.

At a peak output of 20 mW, the transmitted SSB signal third-order intermodulation products are down at least 33 dB. More importantly, the fifth and higher-order product levels drop off rapidly. Keep in mind that as this signal is amplified, it tends to degrade the intermodulation levels relative to the peak output.

Improvements

Suppose we wanted to bring the receiver up to "contest grade"—what changes would be needed? Raising the input intercept point to the +10 dBm level would require a new RF board. We would need to add a high-dynamic-range IF amplifier at 19.665 MHz and add associated switching to get it out of the transmit path. This would lower the noise figure at the first mixer so that we could reduce the gain of the RF amplifier. Next, the RF amplifier and first mixer would need beefing up. The first mixer would end up in the +17 dBm LO class, or greater, and the first-conversion oscillator would need a level increase.

At this point, the reciprocal mixing of phase noise from the first-conversion synthesizer would cover the intermodulation products. It is possible to improve the VCO somewhat to lower the phase noise. But, to reduce the noise to our "contest" level, you would need to raise the present 5-kHz synthesizer reference frequency to perhaps 100 kHz. That would allow a wider loop filter for the synthesizer, which reduces close-in phase noise. This can be made compatible with the 5-kHz step size by one of several techniques, such as using a DDS to set the reference frequency.

Next, you would find that for signals within the crystal-filter passband, the ADC noise limits the dynamic range. The present ADC really has about 12 or 13 bits above the noise level. Around 16 to 18 bits would support the improved performance level. Alternatively, a lesser number of bits running at a higher conversion rate could be used. For SSB and CW, a narrower crystal filter could be used since the fine-tuning could now be done in the fancier synthesizer. FM operation would require a wide crystal filter, of course.

Incorporating all of these changes would significantly add to the transceiver's complexity, but for many that would be justified by the improved performance. I feel that many (most?) of us can be happy with the present level of receiver performance, realizing that we have made a reasonable set of tradeoffs. There certainly are opportunities for future projects!

Future Directions

This transceiver is ready to go for QRP 2-meter operation. For some, this might be the stopping point. But the DSP-10 should be regarded as one building block in a potentially large collection. An obvious add-on is a power amplifier for 2 meters. The transceiver is compatible with many of the single-board transverters described in *QST* over the years. This can extend operation into the UHF and microwave bands. A tuning knob can be interfaced with the PC quite easily, if desired.

One of the best parts of building in software is being able to modify or add in any way imaginable (or at least having that illusion!). The "wish list" for other additions and changes depends on an operator's particular interest. My personal list is oriented towards weak-signal operation and looks like this:

- Add the ability to measure a frequency standard by stealing an occasional second away from reception time. This measurement would include transverters in the signal path so that the overall frequency accuracy could be 10 Hz or better. Eventually it would be desirable to have the transverters synthesized from the station frequency reference.
- Add some weak-signal modes using multitone frequency-shift keying.
- Add the ability to use custom-designed audio filters with real-time downloading to the DSP. (The DSP program already has this capability.)
- Add a 12-kHz concurrent spectrum display. Wider displays could also be added by briefly stopping the transceiver and sweeping the first-conversion oscillator.

There you have some ideas of what could be done with this project. I encourage experimenters to jump in and start writing programs. In general, changes need be made only to the PC program. The DSP unit is quite general in its commands. For instance, those wanting a *Windows 98* interface could develop it in Visual Basic and never need to change the DSP programming at all.

Acknowledgements

I want to thank the many people who have helped with this project: Johan Forrer, KC7WW; Gary Oliver, WA7SHI; Andrzey (Andy) Baranski, PE1ROE and Ernest Manly, W7LHL, have all provided helpful inputs. Special thanks go to Kirk Bailey, N7CCB, for the many discussions that are reflected in the current arrangement of the transceiver.

Notes

[19] Bob Larkin, "The DSP-10: An All-Mode 2-Meter Transceiver Using a DSP IF and PC-Controlled Front Panel,"—*Part 1*, Sep 1999 *QST*, pp 33-41;—*Part 2*, Oct 1999, *QST*, pp 34-40.

[20] An example of the spectral map display is included in the article by Steve Ford, WB8IMY, "A Conversation with Mike Cook, AF9Y," *QST*, Jan 1998, pp 56-57. More information about AF9Y's spectral display program *FFTDSP* is available at his Web site **http://www.webcom.com/af9y**.

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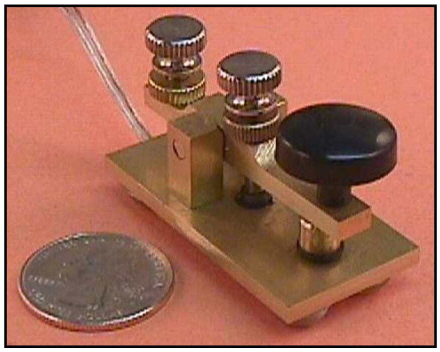

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