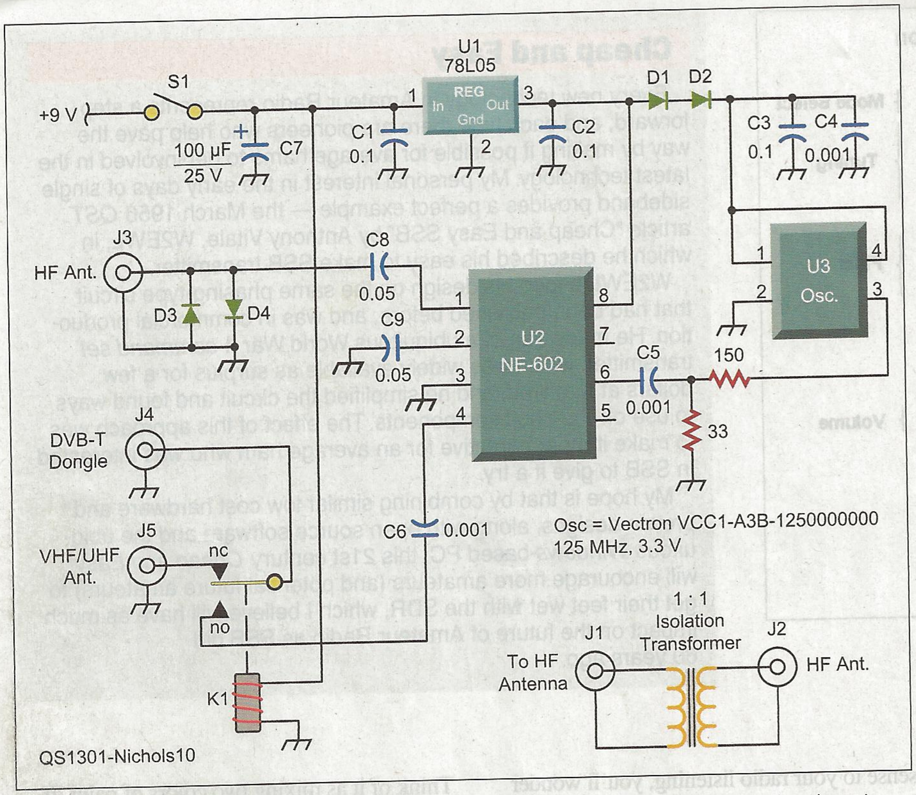

Figure 10 — Schematic diagram and parts list for the HF upconverter for SDR operation down to below the AM broadcast band.

C1-C3 — 0.1 µF, capacitor.
C4-C6 — 0.1 µF, capacitor.
C7 — 100 µF, 25 V electrolytic capacitor.
C8, C9 — 0.05 µF, capacitor.
D1-D4 — 1N4007 silicon diode.
J1-J3 — RCA type panel jack.
J4, J5 — F-type coax panel jack.
K1 — SPDT relay, 5 V coil. Omron G5LA-14-DC5 or equivalent.
R1 — 150 Ω, ¼ W resistor.
R2 — 33 Ω, ¼ W resistor.
S1 — SPST miniature toggle switch.
T1 — RF isolation transformer, 2 turns each side on BN-43-2402 binocular ferrite core.
U1 — LM7805 voltage regulator IC.
U2 — NE-602 mixer IC.

The converter needed for SDR has one big difference when compared with a typical converter hams are familiar with. Normally we would add tunable filters on the input to pass only the signals of interest and reject everything else. Since we want to view the entire HF band, I found that a simple wideband untuned input and output circuit worked well, at least in my location. These design decisions greatly simplify the converter, but those who are located near strong RF sources (such as broadcast transmitters) may need to add some external filtering.

Although the AGC in the tuner works well, it can be overloaded by strong signals. Click CONFIGURE to turn off the tuner AGC and manually adjust the RF GAIN slider as needed for optimal reception.

Figure 10 shows the schematic and the parts list of the HF converter using an NE-602 mixer IC. Separate antenna connections are provided for HF and VHF-UHF antennas. A relay is used to automatically connect the converter if HF operation is desired. If converter power is off, the normally-closed contact routes VHF/UHF signals directly to the DVB-T dongle for normal operation. This makes it possible to locate the converter any desired distance from the DVB-T dongle and select between HF and normal operation by simply switching the power to the converter on or off. The converter can be built on a small PC board, or using perforated project board.

Table 1
Relationship Between the Local Oscillator (LO), Input and Output Frequencies for the 80 and 10 Meter Amateur Bands

Input Frequency (MHz)	LO Frequency (MHz)	Output Frequency (MHz)
3.58	125	128.58
28.5	125	153.50

Figures 11 and 12 show the completed upconverter board and the board in its cabinet. Additional details are on the QST In Depth website (**www.arrl.org/qst-in-depth**).

Inexpensive RG-6U coax and F type connectors are used, as they provide low loss through the UHF range. Input signals from the antenna are coupled to pin 1 of the NE-602 through a broadband coupler and back-to-back diodes that provide isolation and protect the input from static discharges.

Through hole components are used for everything but the 125 MHz CMOS oscillator module, which is only available in a surface mount package, but this component is easily attached with a small-tipped soldering iron. Simply apply a small amount of solder to the pad area, then hold the part in place while reflowing the solder to one pad to hold it in place, then add a bit of solder and reflow the remaining pads. The 125 MHz output from the module is reduced by means of a voltage divider to the proper level required by the NE-602. PC boards are available from FAR Circuits at **www.farcircuits.net**.

Any source of dc power from 9-12 V can be used, but I strongly urge the use of a linear rather than switching type power supply to minimize the potential for switching noise that can cause interference in the converter's output. The 5.0 V output from a 7805 regulator powers the NE-602 and is reduced by approximately 1.4 V by two series diodes to provide the 3.3 V needed by the oscillator. The oscillator draws approximately 50 mA, so a well regulated supply is needed.

Interconnecting wires between the converter PC board and the connectors must be kept short to prevent undesired pick-up of undesired signals. Use fully shielded coax such as RG-6U for antenna interconnections. A USB extender cable may be used to move the DVB-T dongle away from the RFI-noisy PC. As with any receiver, a suitable antenna should be chosen for the type of reception desired on the VHF/UHF bands. For HF, a simple longwire or dipole located away from noise sources will produce good results.

Operating the SDR

Once you experience the fun of having spectral and waterfall displays, it will be hard to go back to using a conventional radio. With just a few hours of use it becomes easy to identify various types of signals, even to the point of recognizing which sideband is being transmitted. It will become easy to click the SDR exactly on frequency.

Using the SDR on HF is no different than on the higher direct frequency range, except everything is shifted up by 125 MHz. While it's

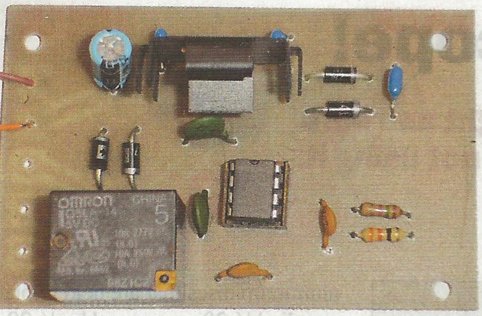

Figure 11 — Assembled upconverter board — ready for final assembly.

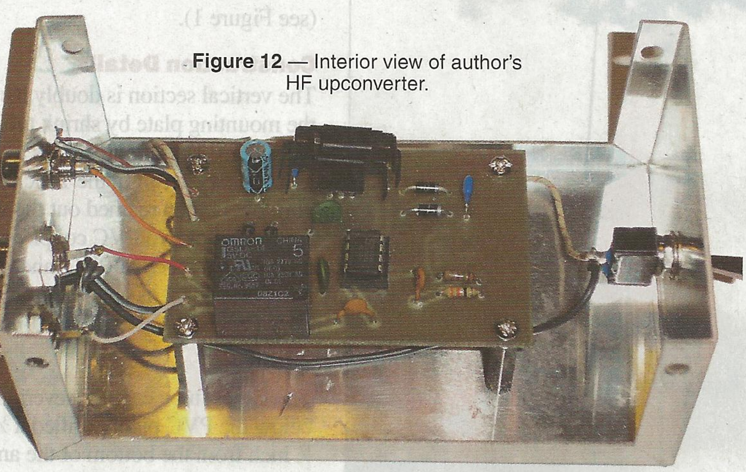

Figure 12 — Interior view of author's HF upconverter.

pretty easy to "do the math," *SDR#* also includes a provision for a frequency shift that will automatically be added or subtracted from the frequency that is displayed and stored in *Frequency Manager*. So, if we enter "–125000000" as the shift, the frequency will be displayed correctly (we use a negative offset because this is the amount to be subtracted from the displayed reading).

As with normal SDR listening with the DVB-T dongle, a slice of radio spectrum up to 2 MHz wide is presented at one time, equally centered about the selected center frequency. So to begin with, Enter "135000000" in the CENTER FREQUENCY box (note the offset is not applicable to center frequency). In normal operation, we would be tuned to 135 MHz in the aircraft band, but with the HF converter switched on, the center frequency is now 10 MHz. With the ZOOM slider all the way down, most North American listeners should see a fairly tall spike near the center of the display. Make sure the AM mode is selected and click on the spike — if you're lucky you will be hearing the sounds of the US NIST time and frequency standard station, WWV from Fort Collins, Colorado.

I've written a guide that explains more about the features of *SDR#* (see references).

The SDR Difference

Few have ever actually seen the entire HF spectrum all at once, but a panoramic view of the whole HF spectrum is possible. It is fascinating to visually see the HF spectrum unfold, and to identify signal types by sight. While I'm not ready to give up my tuning knob, I'd be lost without this added dimension while cruising the bands. You will quickly become adept at visually identifying signals and modulation types, and using the spectrum display to spot unknown signals or open frequencies.

The core of every SDR is the digital signal processing (DSP) software that is used to demodulate and filter the incoming I/Q stream. *SDR#* gives you a choice of several filter algorithms and infinite control of bandwidth to suit your taste or band conditions. Likewise, the waterfall and spectrum displays can be customized as desired.

I suspect that hidden features of the RTL2832 mark the beginning of what promises to be a long journey into the world of SDR. We all remember the idiosyncrasies of our first Novice rig, but also the thrill of learning, and how much fun it was to eke the most performance out of inexpensive and simple gear. That experience was invaluable when it came time to upgrade, as we had a good idea of what features and capabilities to look for in our next rig. Through the power of software, new features and capabilities are only a download away.

For More Information

The following is a partial listing of compatible DVB-T device and Osmocom references.

Osmocom: **sdr.osmocom.org/trac/wiki/RTL-sdr**.

The official *SDR#* website: **sdrsharp.com.**

Shortcut to official download page: **sdrsharp.com/index.php/downloads**. (Note: "Continuous Integration" or "nightly" versions contain the latest enhancements and new features that are not described in this article.)

RTL2832 DVB-T dongle installation information: **RTLsdr.org/softwarewindows**. (Note: The above procedure must be followed before RTL devices can be used with *SDR#*.)

Bob Rich's standing download site for the latest version of his experimental code (including *Auto Tuner* and *Trunking*): **public-xrp.s3.amazonaws.com/Release-latest.zip**.

##RTLsdr and #sdrsharp on Freenode IRC

Yahoo *SDR#* group: **uk.groups.yahoo.com/group/SDRSharp/**.

My own collection of SDR-related info on Google Docs: **tinyurl.com/blsg2or**.

My *SDRSharp* user guide and other information can be found at **goo.gl/suS2w**.

ARRL member and Amateur Extra class licensee Robert Nickels, W9RAN, was first licensed at age 14 in 1965 as WNØOHO in Nebraska. He has a BS from Fort Hays State University in Kansas, and credits ham radio as a major influence during his 35 year career in the electronics manufacturing industry. A holder of three US patents, Bob recently retired from Honeywell, where he held positions as a principal engineer, engineering manager, and strategic marketing director. He currently heads up RAN Technology Inc, a business and technology consulting firm. An avid cyclist and cross-country skier, he enjoys ham radio history and homebrewing, in addition to his main interest — collecting, restoring and operating a growing collection of vintage electronics and boat anchor radios from the last five decades.

You can reach Robert at 2645 East Dr, Freeport, IL 61032 or at w9ran@arrl.net.

For updates to this article, see the *QST* Feedback page at www.arrl.org/feedback.