Copyright (C)2016 ARRL, All Rights Reserved

All-Mode 1 kHz to 1.7 GHz SDR Receiver

Build this simple and versatile high-performance receiver for just a few dollars.

James Forkin, WA3TFS

You can easily build a high-performance multimode software defined radio (SDR) receiver. Also, you can build it for very low cost, and have a receiver that tunes from 1 kHz to about 1.7 GHz in two band segments — below and above 30 MHz. The heart of the receiver is a widely available USB dongle, seen in Figure 1, originally intended for television reception. The dongle is available for $10 to $15 on the Internet. Although there are several versions of dongles available, the best one for this application employs the R850T tuner.

Figure 1 — Purchase a dongle that includes the small whip antenna. Cut and use the supplied cable and connector to save cost and assembly time.

The only connection to your computer is via a USB extension cable that attaches the dongle to your computer. I installed two RF antenna jacks — one for 1 kHz to 30 MHz input and one for above 30 MHz. The 1 kHz to 30 MHz antenna input is always connected through a low-pass filter and an upconverter circuit, as seen in Figure 2. In the low frequency position, S1 also routes power to the upconverter. Select the above 30 MHz antenna jack with switch S1.

Dongle Software and Hardware

Several versions of free software are available for download from the Internet. I use *SDR#* (SDRSharp) with my receiver. You can download and learn all that's necessary to install and configure the software at **www.sdrsharp.com**. The company graciously provides the software free of charge, and also sells their version of a software defined radio as well as other plug-ins to add features such as scanning.

The lower frequency limit of the dongle is around 24 to 25 MHz. These dongles were designed for television and commercial FM radio reception. When re-purposed for HF ham use, an upconverter is necessary to allow reception in the 1 kHz to 30 MHz range. My upconverter contains just a few components and is very simple to build. It converts the below 30 MHz frequencies up to a range that the USB dongle can receive.

The schematic (see Figure 2) illustrates the simplicity of this receiver. Combine the dongle, a switch, some antenna connectors, a mixer and oscillator, a power source (for the oscillator), an LED, a few wires, and an enclosure, and you have a complete receiver. All the complex circuitry is already built into the dongle, and all adjustments are done via user-friendly software.

When re-purposed for HF ham use, an upconverter is necessary to allow reception in the 1 kHz to 30 MHz range.

Theory of Operation

The 100 MHz oscillator (Z2) generates an RF signal that feeds a double-balanced mixer (Z1). This mixer converts the below 30 MHz frequencies supplied by an antenna through the 35 MHz low-pass filter, up to a band of frequencies between 100 and 130 MHz. I chose a 100 MHz upconversion mixing scheme so that the frequency readout on the software display will correspond to the received input except for the first digit. In other words, a received frequency of 7.255000 MHz will be displayed as 107.255000 MHz. A signal at 10.1 MHz displays as 110.100000 MHz, and so on.

The low-pass filter is three capacitors and two T37-2 powdered iron toroid cores, each with nine turns of #28 AWG enameled wire. The low-pass 35 MHz filter design is not the least bit critical — you just want to filter out the frequencies above 100 MHz. My junk box yielded capacitor values within a few of picofarads of the design values. No gain is necessary in this upconverter, as the dongle has more than enough gain to compensate for any loss through the filter and mixer.

Construction

The front view in Figure 3 shows the switch (S1) that activates either the HF or VHF-UP positions by routing 5 V to the internal upconverter when switched to HF. The PWR LED glows green when power is supplied to the oscillator. Power input for the upconverter connects to the front panel jack, and is supplied by a wall plug module producing 9 to 12 V dc at 500 mA. The rear view, seen in Figure 4, shows the USB connector on left, the 1 kHz – 30 MHz antenna connector L, and the above 30 MHz antenna connector H on right.

I built my prototype upconverter on high-quality vector board. This allowed for some trial and error in optimizing the design. Vector board limits layout options

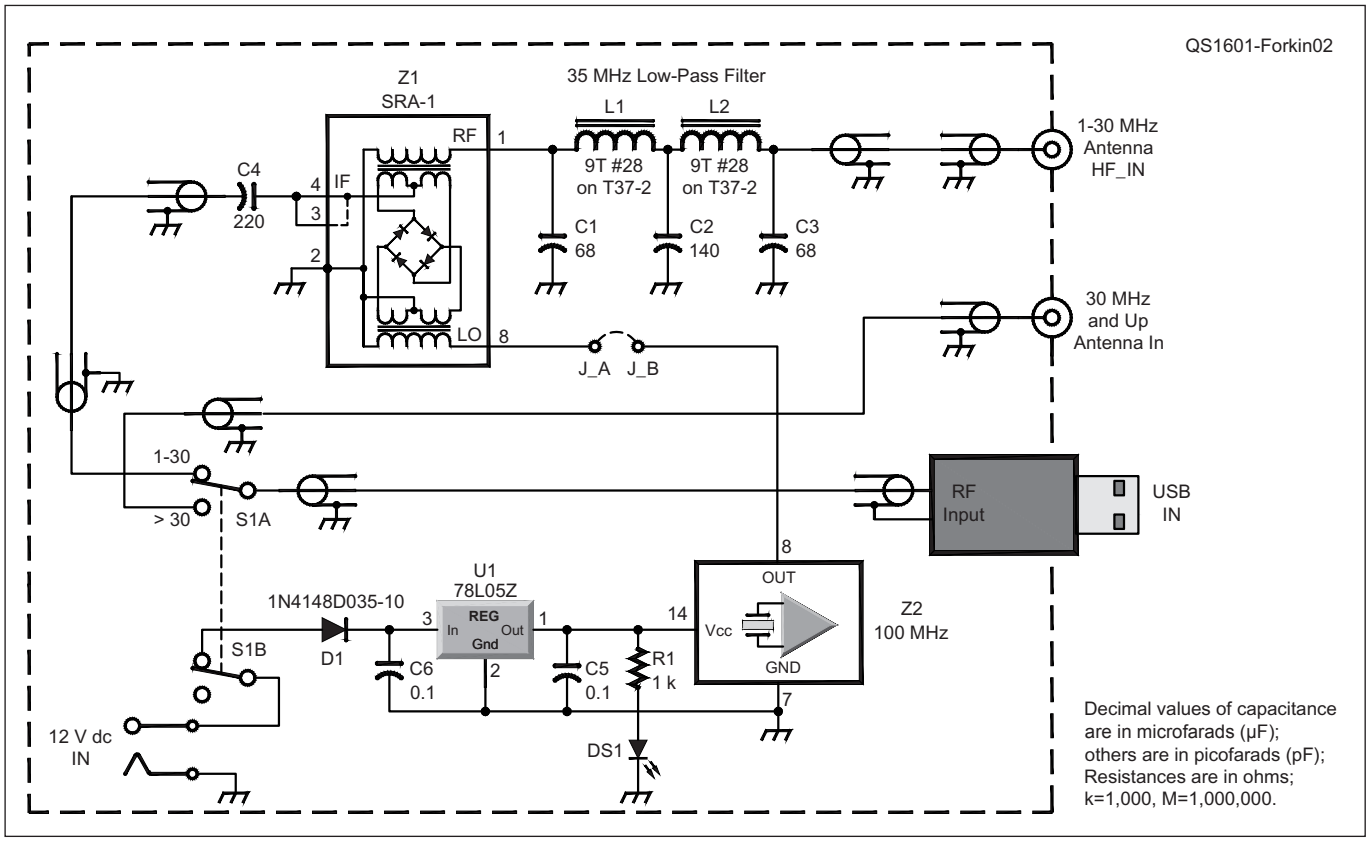


Figure 2 — Schematic diagram of the SDR receiver (DigiKey parts from **www.digikey.com**).

C1, C3 — capacitor, 68 pF ceramic 50 V, 0.197" FK28C0G1H680J, DigiKey
C2 — capacitor, 140 pF ceramic 50 V, 0.197" FK28C0G1H151J, DigiKey
C4 — capacitor, 220 pF ceramic, 0.197" FK28COG1H221J, DigiKey
C5, C6 — capacitor, 0.1 µf ceramic, 0.197" K104K20X7RH5TH5, DigiKey
D1 — diode, GP, D035, 200 mA 1N4148TA, DigiKey
DS1 — LED, select color and size to suit (off board), DigiKey
L1, L2 — 9T #28 AWG on toroid inductor, T37-2 (red) Amidon core.
R1 — resistor, 1000 Ω ¼ W, CF18JT1K00, DigiKey
S1 — DPDT switch (off board), DigiKey
U1 — voltage regulator, 5 V,TO92 MC78L05BP-AP, DigiKey
Z1 — double-balanced mixer, SRA-1, Mini-Circuits, **www.minicircuits.com**
Z2 — Crystal oscillator, 100 MHz, ACO9625 four-pin metal can, Abracon, or surface mount part ECS-3951M-1000-BN-TR, DigiKey
Dongle — search Internet for "R820T USB dongle DVB-T+DAB+FM"
PCB — contact the author, or wire point to point on vector board

Figure 3 — Front view shows the HF and VHF-UP band switch.

Figure 4 — Back view shows the USB and antenna connections.

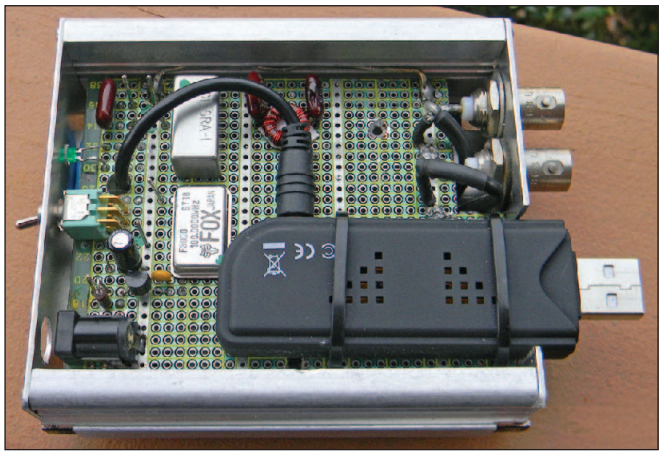


Figure 5 — Fasten the dongle with wire wraps, or double-sided tape, to this vector board implementation of the receiver.

to some extent, but there is plenty of room. I used an SRA-1 double-balanced mixer from Mini-Circuits and a pre-packaged 100 MHz crystal oscillator. There are many different oscillators available. Prices vary greatly, so search the Internet.

Vector Board Layout

Figure 5 shows my prototype receiver completed using a vector board layout. The low-pass filter shown here is of slightly different design that uses a single core with 18 turns tapped at the center.

Follow the parts placement shown in Figure 5 to keep connections short and direct. Attach the dongle to the circuit board using double-sided tape, or hold it in place with wire ties. The RF connector used in the dongle is available but difficult to work with, and can be expensive. Most dongles are sold with an inexpensive wire antenna with 3-foot coax extension (see Figure 1). Cut the coax with the connector attached and use this for the wiring between the switch (S1) and the dongle as in Figure 5. You won't need that antenna.

There are no hardware adjustments necessary because adjustments are done using the SDR software. Although the upconverter can be located remotely from the USB dongle, I recommend that you package it in the same shielded housing for best performance. The entire receiver measures 3 inches by 4 inches when wired on vector board.

[1]www.arrl.org/qst-in-depth

PC Board Layout

I have designed a printed circuit board that would make construction much faster and easier. The details are shown on the *QST* in Depth web page.[1] If you wish to use the receiver only on the HF bands below 30 MHz, you can delete the switch, which disconnects the upconverter from the dongle and re-routs the antenna to the dongle and supplies power to the oscillator. The dongle requires no external power other than that supplied through the USB connection. The upconverter oscillator requires 5 V that is supplied by an onboard 78L05 regulator fed by a 9 to 12 V dc source. A series diode assures no damage will occur if polarity is reversed.

Setup and Operation

You must download, install, and configure the software before using the USB dongle. For best results, do this before connecting it into the upconverter. Download *SDR#* from the SDRsharp web page. Follow the installation procedure detailed on the web page. The software works with any modern version of *Windows* and can also be loaded under *Linux*. Search the Internet for "SDR software" to find several additions and changes available for the software to enhance performance of your SDR. You will also find several other available software packages.

There are no hardware adjustments necessary because adjustments are done using the SDR software.

Once you've installed the software on your computer, plug the dongle into a suitable USB port, activate the software, and you will see the receiver display. Set the receiver on a known frequency such as a local weather channel or public service frequency in the VHF spectrum, and notice the display showing the received signal. Select the proper demodulation, usually NBFM.

Frequency Calibration

Select CONFIGURE and find a selection in the menu to adjust FREQUENCY CORRECTION (ppm). I have found that these dongles have a little bit of drift when first turned on, and then become very stable after a few minutes of warmup. Set the compensation to center the receiver on the signal at the indicated frequency. Turning on the IF DISPLAY makes it easy to see the result of the adjustment. This offset compensates for variations in frequency control in the dongle. Once set, the frequency selected will correspond with the actual received signal. Exit the configuration menu.

The software allows you to also set the filtering width for each mode, the Q of the filter, noise cancellation parameters, squelch in some modes, gain, and so on. It is possible to adjust the receiver to your requirements and adjust the screen display to your liking. Take the time to become familiar with all the possibilities.

Using the Upconverter

Once you have the software and dongle working properly, unplug the dongle and attach it to the upconverter. Attach an HF antenna, plug the dongle into the computer, and apply power to the converter. Activate the SDR software and set the frequency to a known signal such as WWV (110.000000 MHz, including the upconverter offset). Select AM modulation and observe if an adjustment is necessary to align the receiver again. If so, return to the FREQUENCY CORRECTION (PPM) adjustment. This adjustment will compensate for a crystal oscillator that may not be exactly on frequency.

HF Band Operation

You may need to reduce receiver gain in the CONFIGURE selection to keep the dongle from overloading when listening on the HF bands. Adjust the filter bandwidth as required. In some cases you may need to fine-tune to center the received frequency to match the tuned frequency. Use the CONFIGURE menu as described above. When tuning a single sideband transmission, note that the tun-

ing frequency indicated will be above or below the center frequency when tuned to sound correct. This is normal. Adjust the offset for upper and lower sidebands in the software menu used to select demodulation, so the frequency indication is correct when the transmission sounds normal. [The Amateur Radio single sideband standard is to display the suppressed carrier frequency on the dial rather than the center of the SSB modulation. — *Ed.*] Once set, all adjustments are retained.

Adjust the software menus as needed for best reception. There are selections for filter bandwidth in each mode, noise cancellation modes, AGC ON and OFF, favorite frequency memories and other adjustments. It is also possible to record the received audio in a .wav file format. You can also fine-tune both IF and AF noise cancellation parameters, and turn this feature ON and OFF.

Conclusion

You have now constructed a SDR receiver capable of receiving signals in many modulation modes from 1 kHz to about 1.7 GHz. This is an inexpensive way to have a high-performance modern receiver that is suitable for use by beginners or experienced amateurs. It also makes an excellent shortwave and public service receiver. If the bands start to fade, you can listen to your local AM and FM stations. I've used mine to monitor aircraft communication and local police and fire when not using it on the HF ham bands.

The free software supports reception of narrow band FM, wide band FM, AM, upper and lower sideband, and CW. This project is a good introduction to the future of communication, and demonstrates that modern receiver design does not really need to be complicated. You will be amazed at the performance and versatility of this simple design.

Photos by the author.

An ARRL member since 1972, James Forkin, WA3TFS, was first licensed as Novice WH6HOC while stationed in Hawaii with the US Army. He became Advanced class WA3TFS upon returning home to Pittsburgh. Jim retired from electronics design engineering after 45 years working in aerospace, medical, industrial, and electro-mechanical design. He enjoys designing and building receivers and transceivers. Jim operates SSB, CW, AM, and FM and has been active in several Amateur Radio clubs. He has previously published articles in *Ham Radio* and *QST* magazine. You can reach Jim at 3210 Shadyway Dr, Pittsburgh, PA 15227, **jforkin@verizon.net**, or **wa3tfs@arrl.net**.

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

New Video

K1N — The Navassa Island DXpedition 2015 DVD

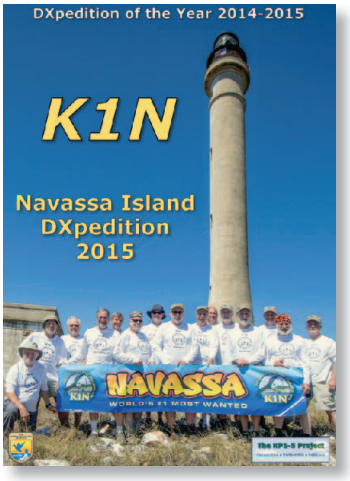
Reviewed by Steve Ford, WB8IMY
QST *Editor*

As I watched *K1N — The Navassa Island DXpedition 2015* DVD, I pondered a rhetorical question: *Who in their right mind does something like this?*

Who would willingly shell out substantial amounts of money and travel to a hot, humid, uninhabited island for the "pleasure" of drinking from an RF firehose? You'd have to be a special sort of individual to extract enjoyment from listening to thousands of amateurs screaming their call signs into your headphones for hours on end as you sample the tasty contents of a package labeled "Meals Ready to Eat," swat ravenous insects, and wonder if the helicopter that deposited you on this godforsaken rock was ever coming back.

Of course, the answer to my rhetorical query is simple: They did it for the love of Amateur Radio, and the pure joy of putting one of the most-needed DXCC entities in the world — Navassa Island — on the air at last.

In *K1N — The Navassa Island DXpedition 2015*, you have a front-row seat for the agony and the ecstasy of the K1N operation. If you were one of the many thousands who snagged a contact with the K1N team, hearing their signal coming back to you was probably somewhat abstract — just a sound or a voice issuing from your transceiver. But watching *K1N — The Navassa Island DXpedition 2015* brings you directly into their world. During this fascinating 45-minute video, you find yourself face to face with the people who gave you that precious "new one," and you gain a new appreciation for what it means to undertake a DXpedition of this magnitude.



As you'll see, Navassa Island is not far from the continental United States, but with no beaches to provide a normal landing, the island might just as well be on the other side of the world. Much of the team had to reach Navassa by helicopter. (If you're a fan of 'copters, you'll particularly enjoy these portions of the video.) Otherwise, getting on and off the island demands that you risk life and limb on jagged cliff faces surrounded by treacherous seas.

In addition to the spectacle of the operation itself, you also see the mazes of bureaucratic red tape the K1N team had to navigate to make this unique operation a reality. At the same time, however, you witness the friendship and camaraderie that was vital to the DXpedition's success. Thanks to excellent narration and video production by Gary Pearce, KN4AQ, the humanity and humor of their experience is evident throughout.

If you're looking for a last-minute gift item for the holidays, you can't go wrong with the *K1N — The Navassa Island DXpedition 2015* DVD. Not only will you (or your club) enjoy an outstanding video, you will be investing in future DXpeditions. *Available for purchase at* **www.k4uee.com/dvd***; $25.*