

Software-defined Radio

by Bert Garcia N8NN and Pete Castella N4CQN

For more than 100 years the equipment required to decode and process radio signals has been analog circuitry. While Software-defined Radio (SDR) technology is not new, having been developed more than 30 years ago, the ability for hams to affordably experiment with SDR has only been possible for less than a decade. The first commercial single-chip RF processor became available in 2009 (1). In 2012 the first really cheap SDR based on the RTL2832U chip became available (2) and now costs less than \$25. Powerful personal computers (you're using one right now!), inexpensive hardware, and free software have made SDR available to every ham. This article describes how you can add an SDR receiver to your station.

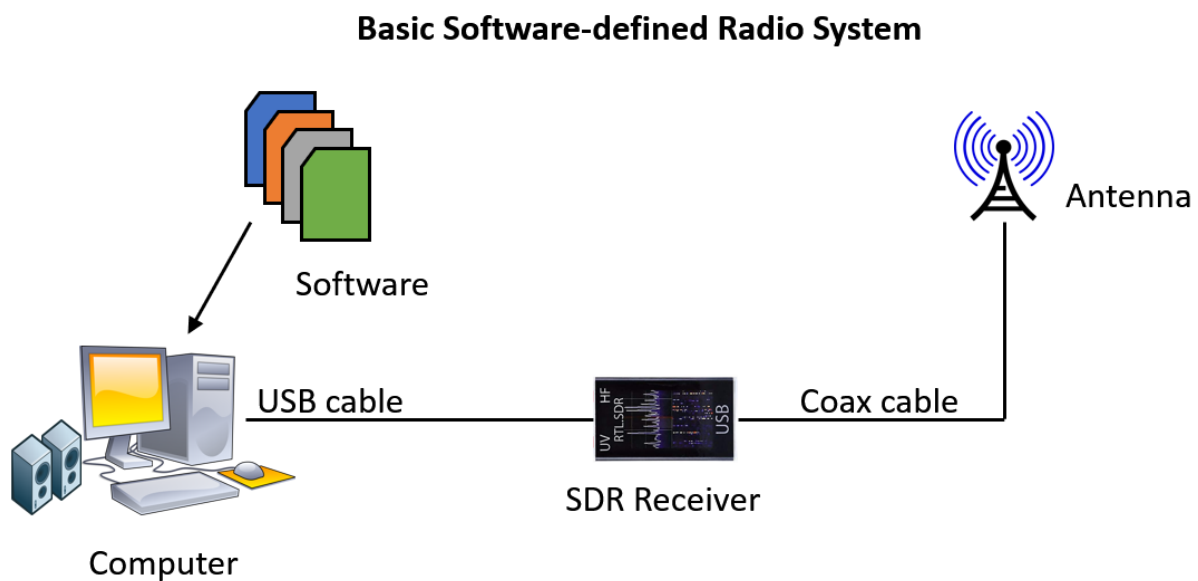


Figure 1: A basic software-defined radio system.

The basic SDR system in Figure 1 is built around an inexpensive SDR receiver connected to an outdoor antenna and using free software on your personal computer. Typically, the SDR is powered by the USB cable, and the antenna connector is a female SMA. Here is a list of affordable SDR receivers for ham use:

1. RTL-SDR RTL2832U Dongle, <https://www.amazon.com/>, \$25
2. Nooelec Lana, <https://www.amazon.com/>, \$30
3. SDRplay RSP1A, <https://www.sdrplay.com/rsp1a/>, \$120
4. Airspy HF+ Discovery, <https://v3.airspy.us/>, \$170
5. HackRF One, <https://www.adafruit.com/>, \$340

The \$25-\$30 SDRs usually only cover about 20 MHz to 2 GHz, having poor performance on many of the HF bands. An up-converter can solve this problem, but now the cost has approached that of the SDRplay and Airspy receivers which cover all the HF bands in addition to

VHF/UHF. The HackRF One is sold as a laboratory instrument and includes a 20 mWatt transmitter and has slipped up and out of the affordable category.

Free software to turn your computer into an SDR receiver is available on the Internet. Some of the hardware requires specific software, so it is usually best to wait until you have your SDR in hand before downloading software. The greatest software problem in making an SDR work is obtaining and installing the drivers required. Your hardware probably won't come with installation instructions, but you will be directed to a website for the software and instructions. Be prepared to read and learn by trial and error!

We selected the SDRplay RSP1A receiver (3) to use as a spectrum display to complement our HF stations. Figures 2a and 2b show how the RSP1A was integrated into our stations. Care needs to be taken so that transmitted RF does not damage the RSP1A. In Figure 2a an MFJ-1708B-SDR antenna T/R switch (5) is used to allow the RSP1A to share the transmitting antenna. A keying line from the radio to the MFJ-1708B-SDR CTRL jack disconnects the RSP1A from the antenna to protect it. If you have a linear amplifier, connect a cable from the MFJ-1708B-SDR AUX connector to the amplifier PTT input.

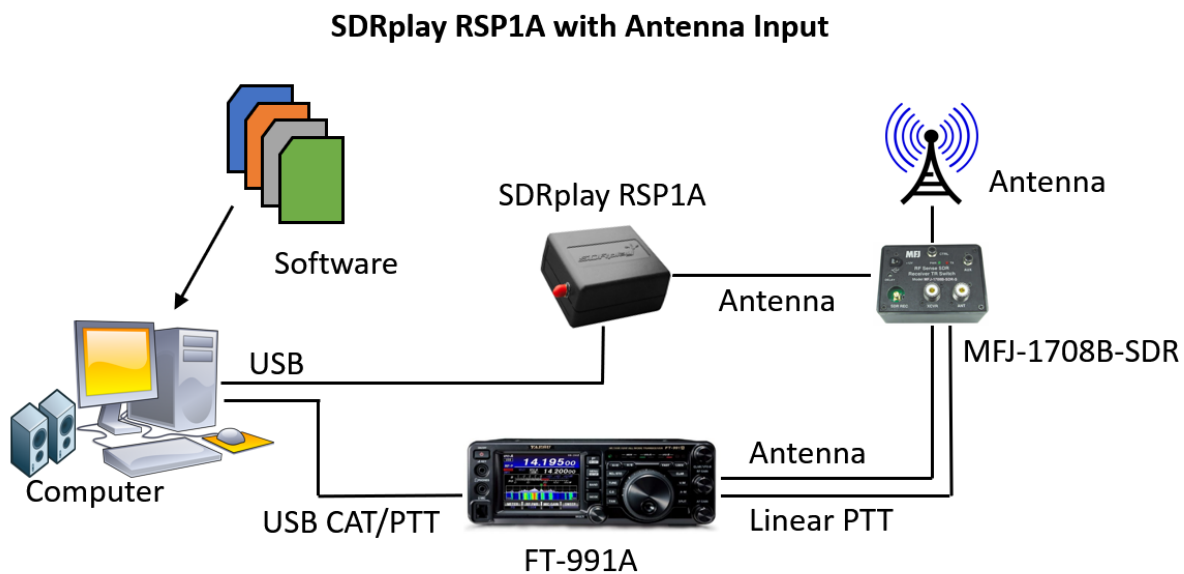


Figure 2a: SDRplay RSP1A with Antenna Input.

In Figure 2b the RSP1A antenna input is connected to the radio 9 MHz IF output, so no RF protection is required.

SDRplay RSP1A with IF Input

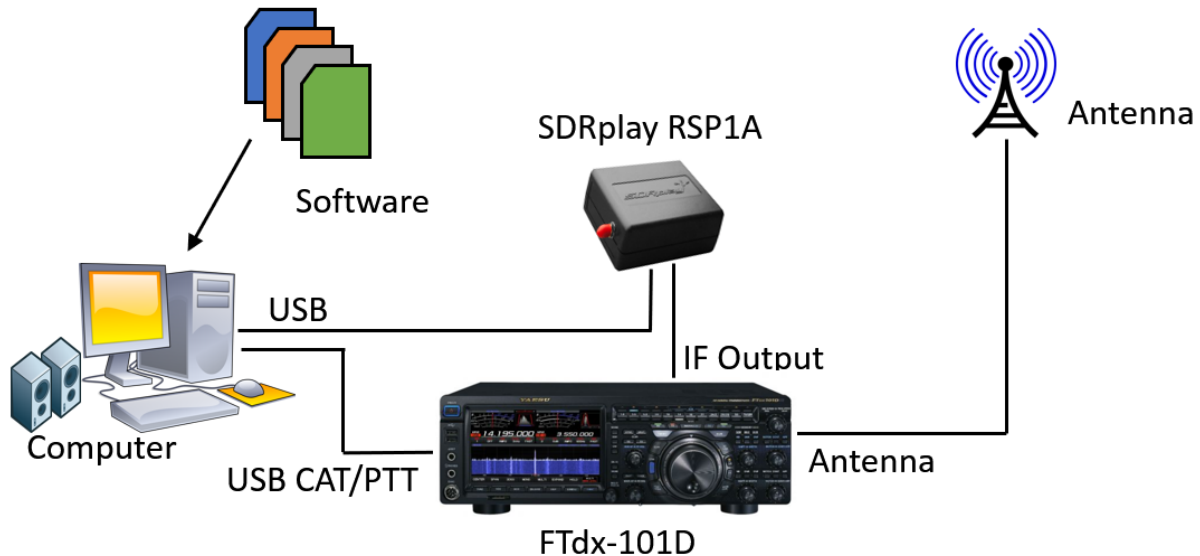


Figure 2b: SDRplay RSP1A with IF Input.

Both the FT-991A and the FTdx-101D have built-in spectrum scopes, so why would one add an SDR receiver to the system? The spectrum display with the SDRplay software has a much higher resolution than the built-in displays. The SDRplay software allows radio tuning from either the SDRplay display with a mouse, the radio dial, or radio touch screen since all are synced together. Clicking on the SDRplay display with the mouse will set the radio frequency, which is very convenient so you can jump quickly to a signal you see on the spectrum display. The FT-991A does not have the capability to add a large screen display, so the RSP1A solves this problem for the spectrum and waterfall display.

Until now, we have talked about the software in general terms, so it's time to get down to the details. You have several choices for the software for the basic SDR receiver in Figure 1, depending on the hardware you purchase. An Internet search will show you what's available. Because of the wide variety of software available for the basic SDR system, we will not discuss the basic SDR system. Instead, we will focus on the SDRplay RSP1A SDR system. Here is a list of the software used for the SDRplay RSP1A SDR receiver:

Required Software:

- (1) SDRUno, <https://www.sdrplay.com/start-here/>, free
- (2) Omni-Rig, <http://www.dxatlas.com/OmniRig/>, free
- (3) LPB2, <http://www.telepostinc.com/LPB2.html>, free

Additional Optional Software:

- (1) Your favorite logging program (* see note below)
- (2) Virtual Serial Port Emulator VSPE, <http://www.eterlogic.com/>, \$25 (recommended)
- (3) Virtual Audio Cable VAC, <https://vac.muzychenko.net/en/>, \$30 (required for CW Skimmer)

- (4) CW Skimmer, <http://www.dxatlas.com/CwSkimmer/>, \$75
- (5) FLdigi, <http://www.w1hkj.com/>, free
- (6) FLrig, <http://www.w1hkj.com/>, (recommended with FLdigi), free
- (*) Logging programs known to be compatible, DX4WIN, ACLog, Logger 32, N1MM Logger+

The SDRplay RSP1A software is SDRuno, available on the SDRplay website. When you receive your RSP1A receiver, you use the serial number to download the SDRuno program. Fortunately, the SDRuno installation includes the hardware drivers required for the RSP1A. Figure 3 shows the SDRuno software panels in operation.

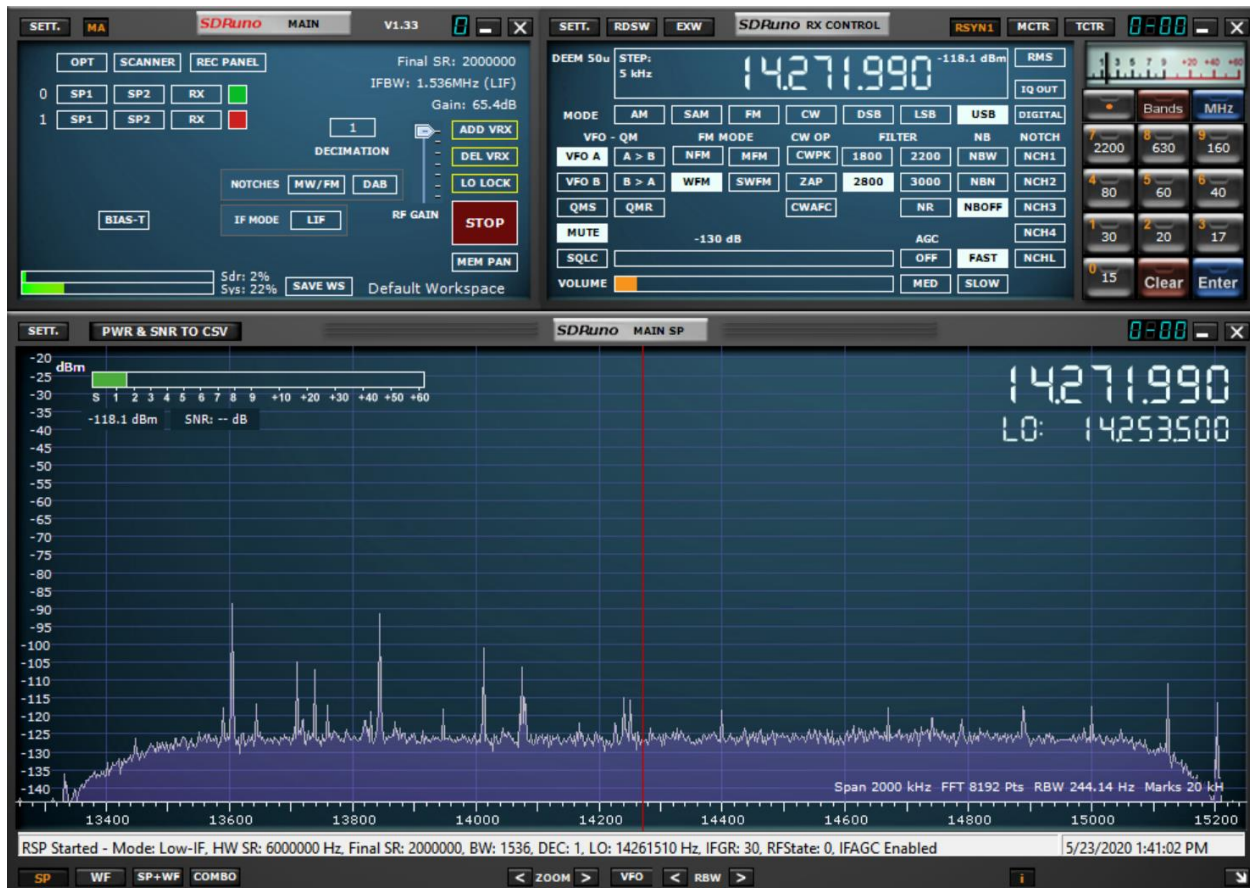


Figure 3: SDRuno panels.

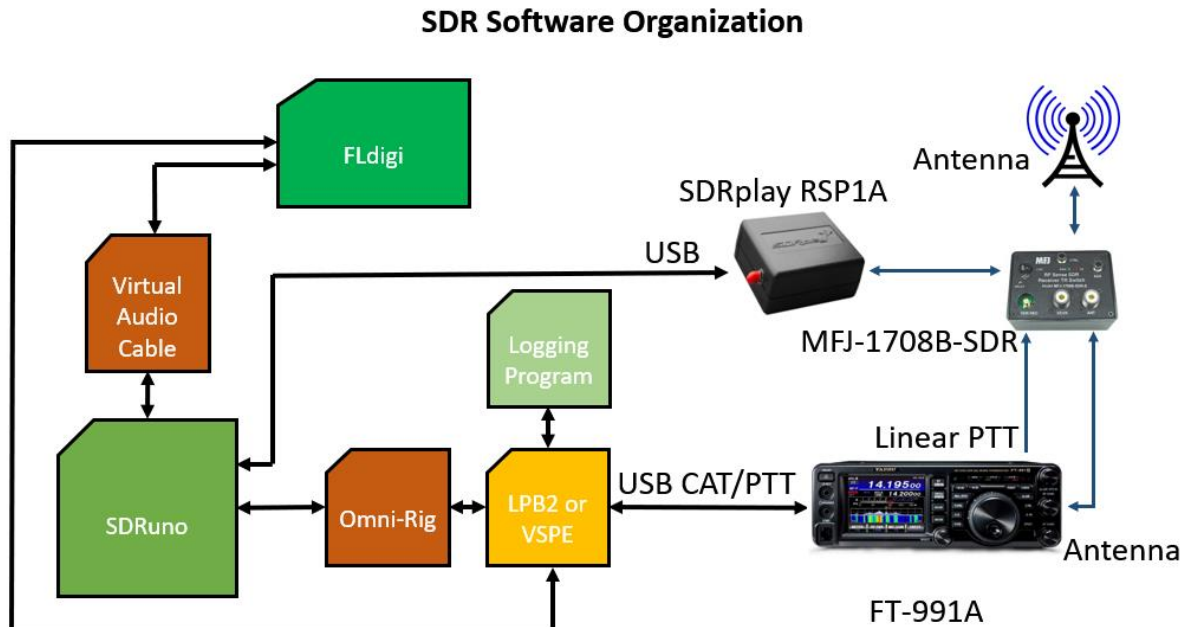


Figure 4: SDR Software Organization.

Figure 4 is a conceptual diagram of the software flow. Since programs like SDRuno, your logging program, and FLdigi are all standalone programs, you need some "glue" to bind them together. LPB2 or VSPE are the programs that allow COM port sharing, and VAC is the program that allows audio sharing. Omni-Rig is a program that translates each radio manufacturer's specific Computer Aided Transceiver (CAT) commands to common data that can be used by many software applications including SDRuno. And herein lies the problem! Many standalone programs perform well at their intended tasks but gluing them together is a challenge. So far, no one has written the Swiss Army knife program to bring all the standalone software together.

A walkthrough of the required software follows below; but before you start, consider these basic recommendations:

- (a) Keep a written record of all your settings and update it frequently. Make screen grabs of your settings windows.
- (b) Work slowly using a building block approach. Start with a basic SDR system, get it working, and record the settings. Then add one component, get everything working, and record the settings. This way you have a fallback position when things go wrong.
- (c) Use the same baud rate on all COM ports. If your radio will only run at 4800 baud, use that for everything. Mixing baud rates will only mix you up.
- (d) Do not reuse a COM port number assigned to a physical COM port. It will not work. If your software application needs to reach a physical COM port, use a virtual COM port utility such as LPB2 or VSPE.
- (e) Use one COM port for CAT control and use a different COM port for CW keying and PTT. This is a Yaesu requirement, and your radio may handle CW keying and PTT differently.

- (f) In general, use RTS set to ON or HIGH in all applications. Again, a Yaesu requirement.
- (g) Use DTR for CW keying, if needed. In some installations you may have a separate COM port for CW keying or for a WinKeyer. If possible, use DTR as the standard for CW keying.

Start with a basic SDR system like Figure 1. Do not connect your SDR receiver to your computer until instructed to do so during the software installation. Failure to follow this instruction could land you in a driver installation nightmare when Windows decides to install some generic driver! The software used here has been verified to work on Windows 8 and 10.

For SDRplay, go to the Start Here page <https://www.sdrplay.com/start-here/>, fill out the form, and continue with installing SDRUno. When installation is finished and your RSP1A and antenna are connected, the SDRuno Main panel will open. Click on SP1 for receiver 0 (zero). The Main SP panel will open and show a spectrum display. The Main panel will show a green box for receiver 0. Increase the RF gain slider as high as possible without getting an "overload" warning. Click the red Stop button; it will turn green and say Play!. Your SDR receiver is working! Poke around and see what you can hear. Your receiver controls are on the RX Control panel where you will find the volume control, mode selections, and the frequency display. If you don't see the RX Control panel, press the SP2 button. The number of SDRuno panels that open will depend on the resolution of your computer screen.

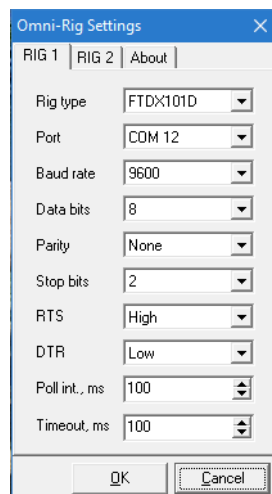


Figure 5: Omni-Rig Settings window.

With a working SDR receiver you are now ready to add your transceiver to the system. Install Omni-Rig <http://www.dxatlas.com/OmniRig/>. Figure 5 shows the Omni-Rig Settings window. In the Settings window select your rig type and the physical COM port for CAT control. Set baud rate, data bits, parity, stop bits, RTS, DTR as required for your radio. For Yaesu radios use 9600, 8, none, 2. Older Yaesu radios require 4800 baud; newer Yaesu radios default to higher baud rates. Set RTS to High; set DTR to Low; leave the other settings at the default. Click OK and you are ready to go. Your radio should be connected to the COM port and turned on or you will receive a warning message. Be sure to set the radio internal menu items to match your Omni-Rig settings. The COM port numbers used in this article are examples only.

Now go to the RX Control panel in SDRuno and click on the RSYN1 button to connect to Omni-Rig and your radio. The button will turn orange and SDRuno is now communicating with your radio. Click in the Main SP panel and the radio frequency will change to the same frequency you clicked on. Turn the tuning dial of your radio and the frequency displayed on SDRuno will change. It's working! You now have an SDR system as shown in Figures 2a or 2b.

It's now time to add your logging program to the system. Here is where the real challenge starts. Your logging program wants access to your radio CAT COM port for frequency and mode information, but that COM port has already been assigned to Omni-Rig for use by SDRuno. You need to add a virtual COM port sharing utility. LPB2 <http://www.telepostinc.com/LPB2.html> is a free program that was specifically written to share COM ports for ham radio applications. It supports the Elecraft K2, K3, newer Yaesu, and Kenwood to allow SDR software to access the radio for interactive control, as well as allowing multiple programs to talk to the radio at the same time. LPB2 allows two programs full access to the radio and allows up to four additional programs to read the most common rig parameters such as frequency and mode. Figure 6 shows the LPB2 Control window.

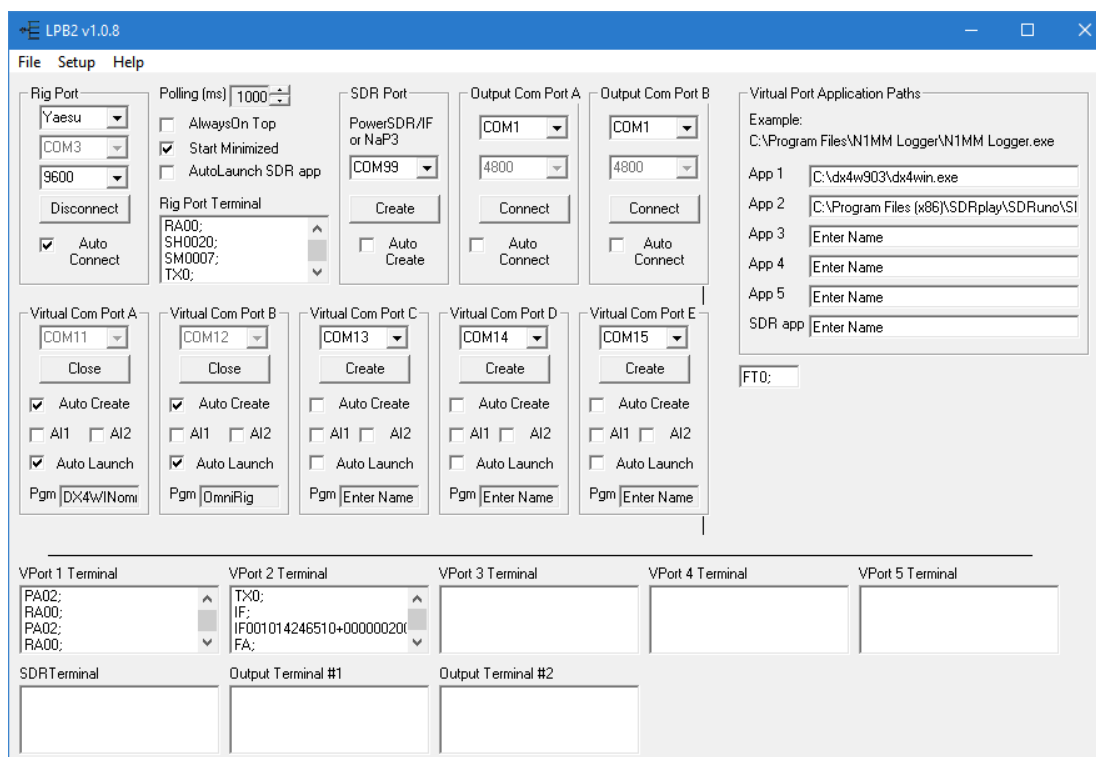


Figure 6: LPB2 control window.

LPB2 will connect to your radio CAT COM port and allow both Omni-Rig and your logging program to share the physical COM port on your radio. However, you have already assigned the physical COM port to Omni-Rig, so you need to change the COM port setting in Omni-Rig to a virtual port that LPB2 will provide. The two virtual COM ports in Figure 5 are COM 11 and

COM 12. Your logging program will use COM 11 and Omni-Rig will use COM 12. Change the Omni-Rig port to COM 12. Other than assigning the virtual COM port number in your logging program, no other changes are needed in your logger. Enter the full path and file name in the Virtual Port Applications Path fields so that LPB2 can start your applications automatically when you start LPB2.

Since LPB2 will only allow two programs full access to the radio CAT COM port, you cannot add more programs unless you "disconnect" either SDRuno or the logging program from your system. A more versatile virtual COM port program is needed. That program is Virtual Serial Port Emulator (VSPE). VSPE is not free, but it will allow up to four programs to share a single physical COM port.

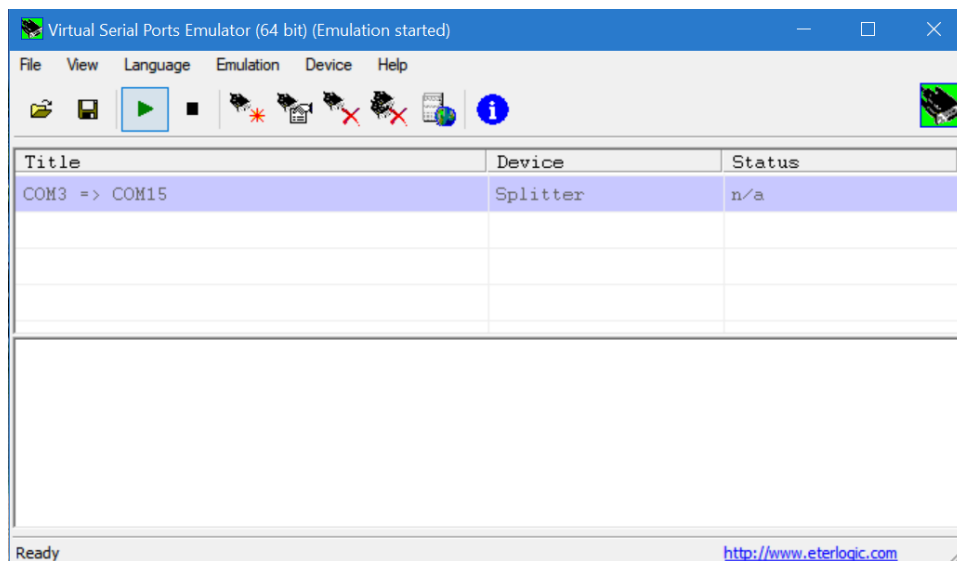


Figure 7: Virtual Serial Port Emulator VSPE.

Start VSPE and create a Splitter with the radio COM port and a virtual COM port to be shared. In this example the virtual COM port is 15. Set the Rig COM port in Omni-Rig to COM 15. Set your logging program to COM 15. You can use the same COM port number here because these are virtual ports, not physical ports. Save the port settings in VSPE. Always start VSPE and open the settings file before any other program so the COM ports are available when other programs start. Next, start your logger and SDRuno. You now have three programs running and sharing data.

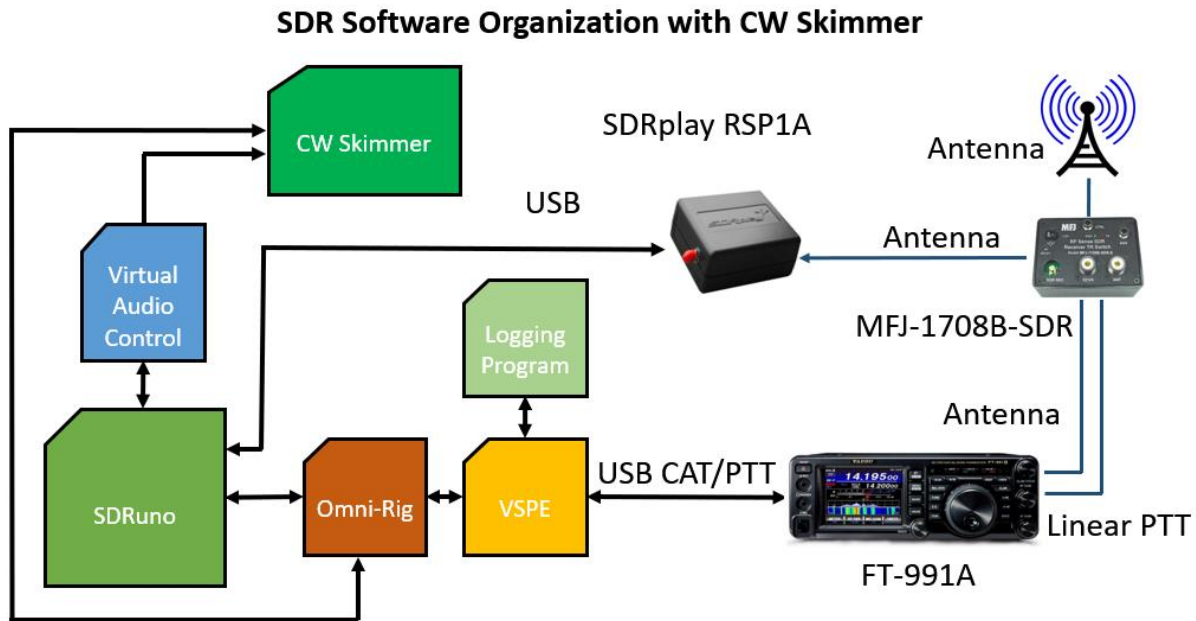


Figure 8: SDR Software Organization with CW Skimmer.

Now, let's add CW Skimmer to the system <http://www.dxatlas.com/CwSkimmer/>. This requires directing the audio output from SDRRuno to the audio input of CW Skimmer. Both CW Skimmer and SDRRuno are software programs, so a physical audio cable will not work. You need a virtual audio cable to connect them together, i.e., you need some more "glue".

VAC <https://vac.muzychenko.net/en/> will connect the audio from SDRRuno to CW Skimmer. After installing VAC set the Cable to 192000 in both boxes. In the SDRRuno RX Control panel, click on SETT > OUT and select VAC for the output device. In CW Skimmer go to View > Settings > Audio Signal I/O Device and select VAC. Under Audio I/O Device you select your normal computer audio device.

CW Skimmer is a multi-channel CW decoder and analyzer which listens to the signals in the receiver's passband from SDRRuno via VAC. It creates a definition by color and highlights for each received signal. CW Skimmer uses algorithms to decode callsigns. If it receives a callsign twice in a message, it makes the callsign bold to alert the user. There is a Telnet Cluster function that can connect to the Internet and receive DX spots.

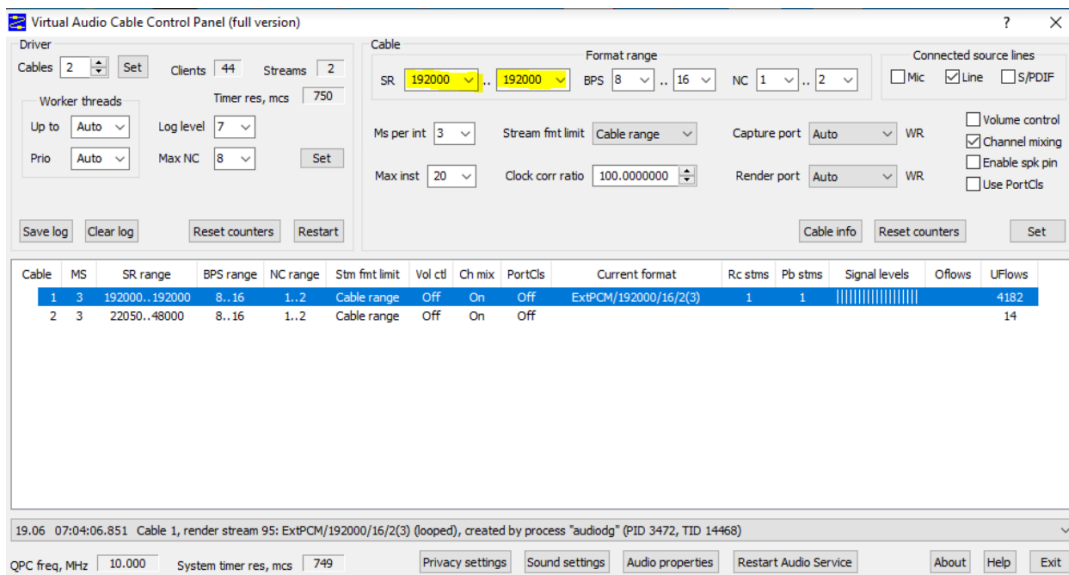


Figure 9: VAC control panel.

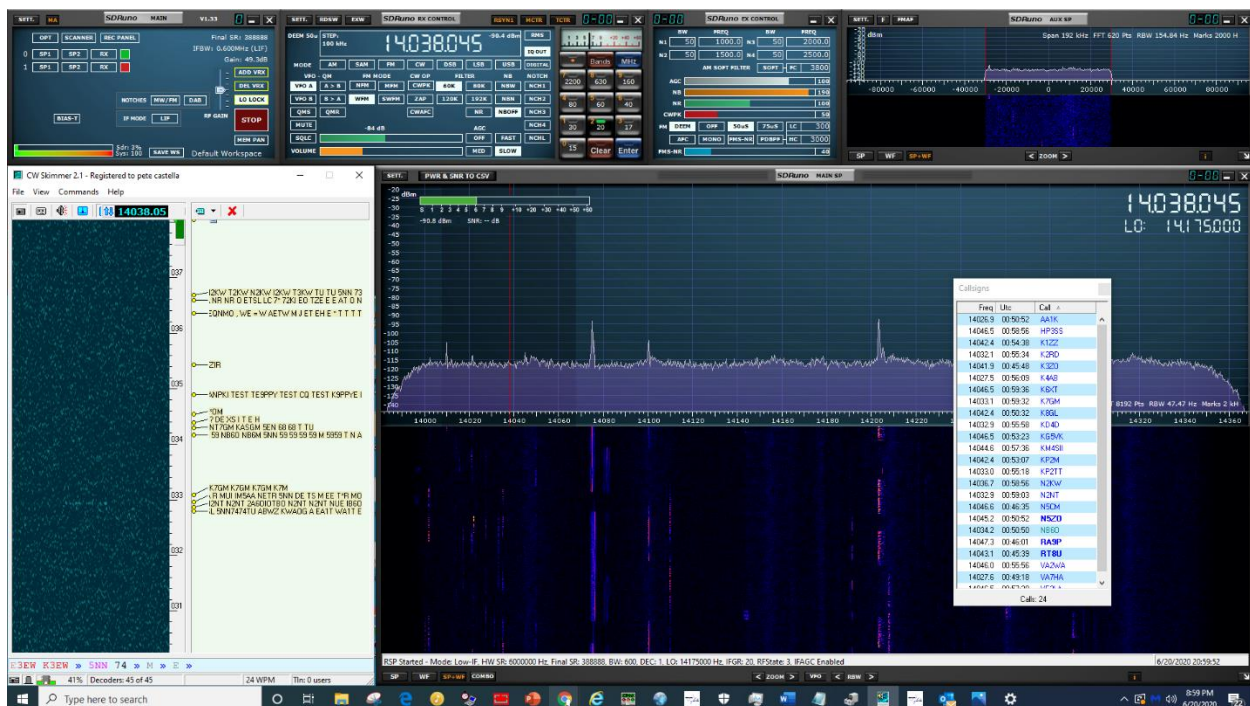


Figure 10: CW Skimmer (left) with SDRuno.

To connect CW Skimmer to your radio, go to Configure, which opens Omni-Rig. Under Rig 1 use one of the virtual COM ports you created in VSPE with the Splitter function. This will allow CAT control from CW Skimmer to your radio. In the SDRuno RX Control panel, click on RSYN1 so it is highlighted. That will activate ORIG in the Main Menu window. Under the Main Menu settings under ORIG you will see Rig 1 and Rig 2, and that it connects to the Omni-Rig Server. In this configuration you will not be using the CW tab, but rather the IQ OUT to send the code to CW Skimmer. When you open your logging program, such as ACLog, it must be on a separate

physical COM port and not a virtual COM port to send CW. For Yaesu radios this is the Standard Port. You have now added a system to your radio that will receive CW signals, display the callsigns and contents being transmitted, and you can send CW from your logging program to make contacts.

This has been a lengthy discussion about adding a Software-defined Radio to your transceiver to enhance its capability by adding improved spectrum visibility and CW decoding and transmitting. Our goal was to spark your interest in SDR and provide enough guidance for you to install and operate multiple programs simultaneously with your radio.

Acknowledgements: We appreciate the thoughtful and skilled assistance of Tim Moore K4TK without whom this project would have taken much longer to accomplish, Mike Ladd KD2KOG for his numerous YouTube videos about SDRuno and his helpful hints for installing multiple programs concurrently, Pete Smith N4ZR for his comments about CW Skimmer, and Alex Shovkoplyas VE3NEA who developed CW Skimmer.

References:

- (1) A short history of SDR technology: <https://www.nutaq.com/blog/short-history-software-defined-radio-sdr-technology>
- (2) *The Hobbyist's Guide to the RTL-SDR* by Carl Laufer: available on <https://www.amazon.com/>, free Kindle Unlimited
- (3) SDRplay RSP1A: <https://www.sdrplay.com/rsp1a/>, \$120
- (4) MFJ-1708B-SDR TR Antenna Switch: <https://mfjenterprises.com/>, \$120
- (5) Sources for software are contained within the article