Using SDR IQ Recordings

This month Mike Richards G4WNC is taking a closer look at using SDR IQ recordings in amateur radio.

Fig. 1: Popular Samsung USB-3 1TB external drive.

One of the most powerful and perhaps least used features of SDR receivers is the access they provide to the raw IQ samples. In most cases, we simply pass these to the decoding software so that it can do its magic to control bandwidths and to demodulate the desired signals. However, in the signals intelligence world, it's the raw IQ streams that are of primary interest because they can be stored and digitally processed to extract all manner of useful information such as searching for key phrases and the like. We can also make use of the IQ data streams to reveal more about the activity on our amateur bands.

As we have discussed previously, the IQ samples from the receiver contain all the information necessary to reconstruct and demodulate a slice of the RF spectrum. When it comes to recording the information, IQ samples are simply a pair of data signals that can be recorded and stored just like any other digital information. The IQ samples format is also very similar to stereo audio signals, so it's become common practice to make use of the WAV (.wav) file format. This file format has the benefit of being lossless

and has the flexibility to handle a wide range of data types. The size of a WAV file has to be kept below 4GB but it can handle many different sample rates so it's ideal for IQ recording.

Most SDR transceiver software will include recording facilities but it can often be better to set up a separate receiver and antenna for spectrum monitoring rather than to tie up your main rig. Suitable receivers include the excellent FUNcube Dongle Pro+ or maybe an AirSpy or the, recently price reduced, SDR Play. For a really cheap solution albeit with lower performance, the RTL based dongles can be very useful, especially when combined with an up-converter for HF operation.

Why Spectrum Recording

Local spectrum recording can be extremely useful for contest operators because it provides a record of your QSOs so that you can double-check your log or maybe clarify a call that's been badly recorded. About a year ago, I spoke to one of the RSGB contest organisers who told me that they were considering making IQ recordings of contest activity to help validate contest logs. Using this technique, it would be very easy to replay the IQ recording, scroll to a specific time/frequency and check that a

logged QSO actually took place. Clearly this is impractical for all QSOs because some would be inaudible to the monitoring station but it could be a very effective way to verify samples from a contest log. The organisers of the CQ contests (see *HF Highlights* in this issue) now routinely make IQ recordings, using volunteers with SDR receivers at strategic locations around the world.

IQ recordings can also be useful for activity analysis on a new band. By running a recording over an extended period, you will be able to see when the band is active, what modes are in use and which regions are active. These recordings can also be powerful tools for tracking down interference problems. By monitoring the target spectrum over an extended period, you will easily be able to see whether the interference changes with the time of day or with other factors, which may provide a useful clue as to the source.

Practical Recording

As you can imagine, recording large sections of RF bandwidth can take up a lot of disk space so it's worth spending some time to consider what you need to record. For HF and LF operators, most of the amateur bands are relatively narrow but once you get to 28MHz and beyond, the bands can be several megahertz wide so you may need to target your recordings to a particular band segment of interest.

The file size of your IQ recording is directly proportional to the IQ sample rate and the size of each sample, that is to say, 8 or 16-bit. When using the RTL based dongles, 8-bit sampling is fine but when using any of the better SDR receivers, 16-bit should be used. The file size can be calculated directly from the number of bits being stored and the sample rate. Let's try a quick example. Recording a 200kHz slice of spectrum using 16-bit IQ samples would require four bytes (8-bits each) for each combined IQ sample so the file size would be 4 x 200,000 = 800,000 bytes per second or 0.8MB/s, which equates to 48MB/minute or 2.88GB/hour. These figures are based on 1000 bytes per kilobyte (kB) and 1000kB per gigabyte (GB) and are good enough for estimating file size. A more accurate result would come from using 1024 as the trigger for the next size. So there would be 1024 bytes in a kilobyte, 1024kB in a megabyte and 1024MB in a gigabyte. While 2.88GB/hour may sound like a lot of space, hard disk prices have plummeted over recent years and 1TB (1024GB) drives are currently available for just £40, **Fig. 1**. In the example I've used here, a basic 1TB drive could store nearly 350 hours of RF spectrum recording. When recording a 48-hour contest, a

200kHz wide segment would only use just over 138GB of disk space. If your PC is short of space, it could be well worth buying another 1 or 2TB drive and using it solely for IQ recordings. In most cases, IQ recordings are only required for short periods so the storage can be reused.

If you've been reading carefully, you will recall that we have a size limit of 4GB for our WAV files so you might wonder what happens if our recording is bigger than this. The answer is simple – we break the file into smaller chunks. Most recording software gives you the opportunity to specify the break point so that files can be automatically split. The most commonly used file size is 1GB.

Players for IQ files are able to read all the key information such as centre frequency, time and so on either from the file name or by using separate data files that are stored in the same directory as the recording, **Fig. 2**. This allows the SDR receiver's player to replay seamlessly, despite the use of multiple files. Although most SDR software uses WAV files to store IQ recordings, the differences in time/frequency marking mean that you generally need to replay IQ files through the same application that made the recording.

If you're using an SDR transceiver for recording, you'll need to refer to the manual for details of the IQ recording and replay facilities. However, if you're using a separate receiver/dongle for IQ monitoring and recording, the chances are that you'll be using SDR Sharp or SDR-Console because these seem to be the most popular SDR packages.

SDR-Console, in particular, includes an excellent IQ recorder and, as I will show later, has some very advanced IQ analysis tools. For those new to software defined radio, SDR Sharp is a popular choice because the user interface is very easy to learn. SDR Sharp also has an integrated IQ recorder and player but the functionality is rather basic. For that reason, I strongly recommend that you install **Vasili's** Baseband Recorder. This is available via the Plugins menu on the **sdrsharp.com** website. Scroll down the list of plugins and you will see Vasili's Recorder listed near the bottom of the page. Click the link and you will be taken to his Russian page. Don't panic, just select English in the Google Translate panel at the upper right of the page and all will become clear, **Fig. 3**. At the time of writing, the Updated Recorder was listed at the top of page 2 on Vasili's site. When you find the link, click on the download button to download a ZIP file to your PC. To install the recorder use the following process:
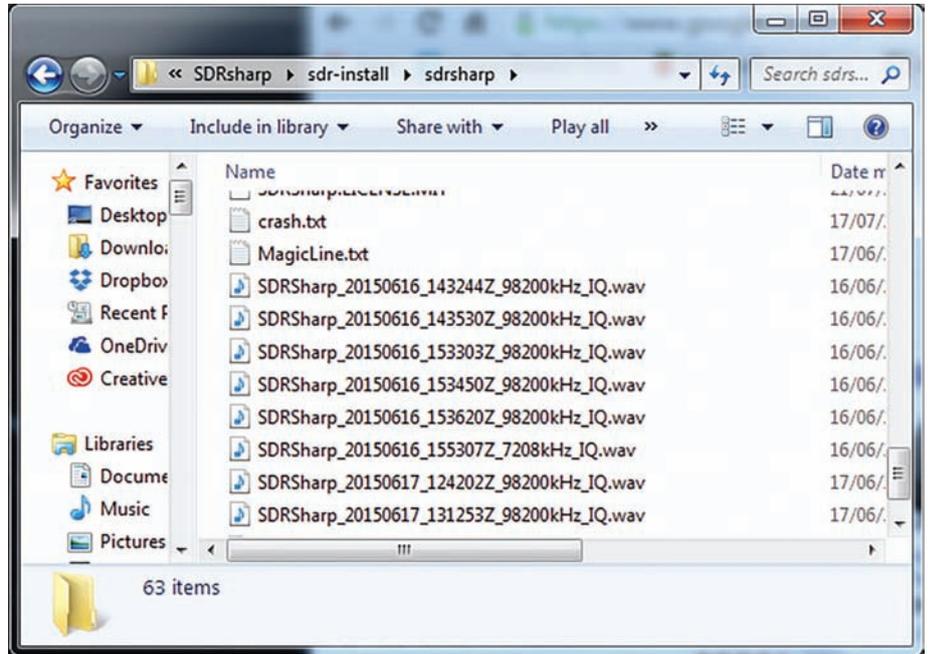
Fig. 2: An example of the IQ file naming used by SDR Sharp.
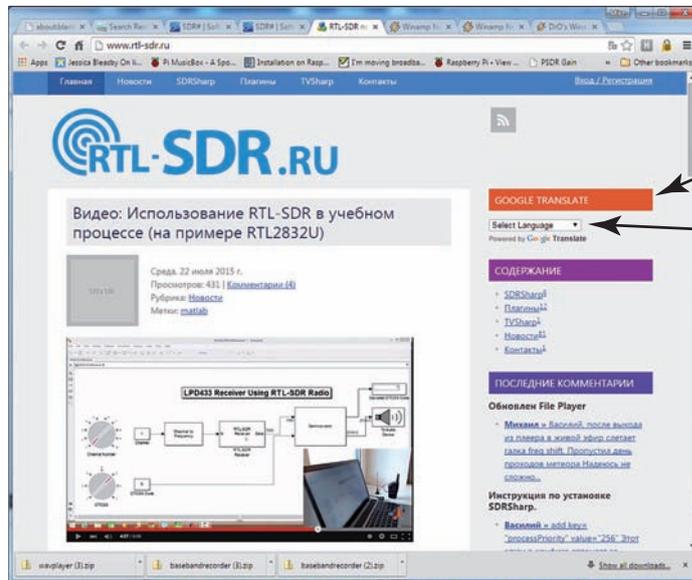
Select language and click Google Translate

Fig. 3: Vasili's Russian website for SDR Sharp plug-ins.

1. Expand the contents of the ZIP file to the directory where SDR Sharp is installed.
2. Open the file named MagicLine.txt.
3. Copy the contents to the clipboard and close the file.
4. Open the file Plugins.xml.
5. Add a new line before </sharpPlugins> and paste the text from the clipboard into the new line (Control V).
6. Save Plugins.xml, restart SDR Sharp and you should find the Baseband Recorder listed at the bottom of the left-hand panel.

It's also worth upgrading the file player in SDR Sharp to Vasili's Updated File Player. At the time of writing, this was located near the top of the first page on Vasili's site. Once you have the ZIP file, use this process to install it:

1. Expand the contents of the ZIP file to the directory where SDR Sharp is installed.
2. Open the file named MagicLine.
3. Copy the contents to the clipboard and close the file.
4. Open the file SDRSharp.exe.Config.
5. Find the section that starts with <frontendPlugins>.
6. Add a new line to that section and paste the clipboard into that line.
7. Save SDRSharp.exe.Config and restart SDR Sharp. The new File player will be shown in the drop-down list of sources at the top-left of SDR Sharp.

Vasili's new Baseband Recorder lets you choose the storage location, stipulate the maximum file size and allows scheduled recordings. This latter feature can be particularly helpful. The Updated File Player also improves the usability and gives you an extra panel that can be used to quickly jump to any point in the recording, **Fig. 4.**

SDR-Console is supplied with excellent

recording and playback facilities included as standard so there's no need for any add-ons. The recorder even has a handy calculator so that you can quickly estimate the file size of your planned recording. The recording and playback controls can be found via the Display tab listed as Data (IQ) Recordings.

Advanced IQ Analysis

Simon Brown HB9DRV has been doing a sterling job for many years by providing us with advanced SDR receiver software. The current offering is SDR-Console V2.3, which works with most of the common SDR receivers and includes a sophisticated IQ analysis tool – the SDR Data File Analyser. This is a stand-alone analyser that's installed with SDR-Console and has been designed to aid the detailed analysis of IQ recordings made with SDR-Console. The first task is to make your IQ recording and that is done using the recorder that's built into SDR-Console as described earlier.

Once you've recorded an IQ data file, the analyser can be used to take a closer look at the content. The only snag is the requirement for a 64-bit PC. This is because the file analysis uses lots of memory and demands 64-bit addressing along with the additional processing power of a 64-bit machine.

To better understand what it can do, let's look at an example. I used AirSpy with an SV1AFN Up-Converter to make a six-hour 156kHz wide recording of the bottom-end of the 20m amateur band. I've shown the result in **Fig. 5**. As you can see, this shows all the activity on the band over a six-hour period in a single, waterfall style, graphic. If you then right-click on any part of the display, you have the option to open a player that will replay and demodulate the signal wherever you click. This makes checking out signals extremely easy and you can move to any frequency/time combination very quickly. In cases where the activity is very crowded, you can use the zoom tool to draw a box around the desired part of the spectrum. This triggers a new project panel, **Fig. 6**, where you can fine-tune the spectrum and time slots to be analysed. When complete, you're presented with a new analysis that covers the zoomed area of the spectrum. From here, you have access to the same tools as before so you can click anywhere on the graphic and start the player or view a signal strength/time graph. If you have enough screen space or multiple monitors, you can zoom into several parts of the spectrum and have all the results windows on display.
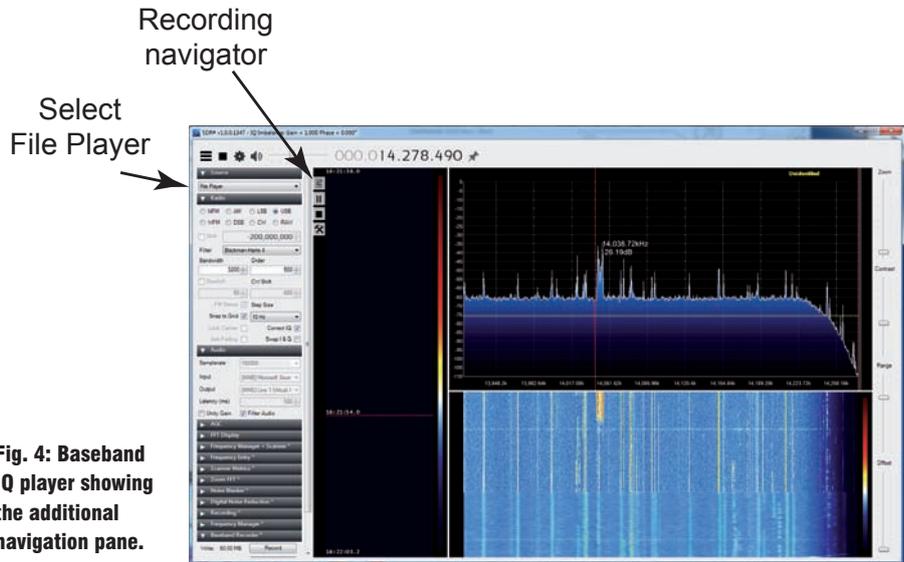
Fig. 4: Baseband IQ player showing the additional navigation pane.
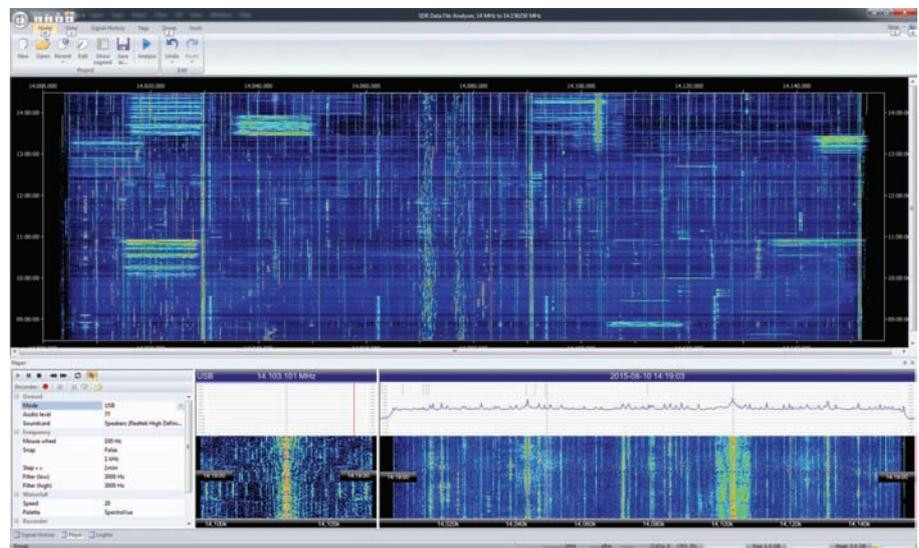
Fig. 5: SDR Data File Analyser showing the spectrum graphic for six hours of 20m band activity. The file player can be seen at the bottom of the spectrum display.
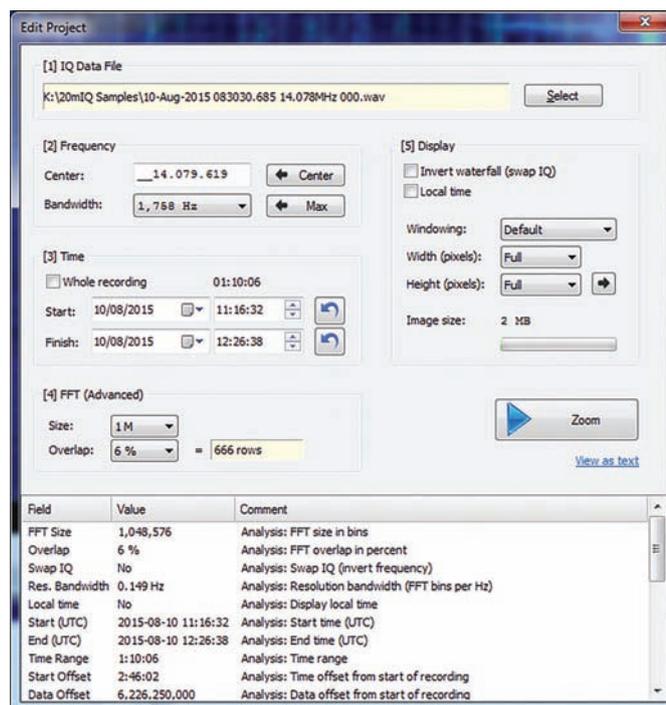
Fig. 6: The zoom project panel that enables customisation of the spectrum zoom feature.