



Filters and Spectral Displays

In *Data Modes* this month Mike Richards G4WNC looks at filtering and identifying signals when a software defined radio receiver is used.

Welcome to *Data Modes (DM)*. This month I'm continuing my examination of software defined radio (SDR) receiver technology with a look at filtering followed by some tips on signal recognition using the spectrum and waterfall displays

One of the exceptional features of all SDR receivers is the quality of the filtering. When using digital filtering techniques it's possible to produce performance and flexibility way beyond that available in even top quality professional receivers of just a few years ago.

Digital filter techniques allow the user to create filters with extremely steep sides, excellent stop-band and minimal ripple throughout the passband. So how is this achieved in practice?

Filter Creation Process

The filter creation process begins by defining the required filter shape and then applying this to a mathematical reverse Fast Fourier Transform (FFT) process. You'll recall from last month that FFT's divide the frequency spectrum into a number of narrow 'bins' each of which represents a narrow band of frequencies

In the reverse FFT process you apply coefficients to say what frequencies you want and those you want to exclude – see Fig. 1.

The type of filter most commonly employed in SDRs is the Finite Impulse Response or FIR filter. This is one of the simplest types of digital filter and is relatively easy to design, implement and importantly for radio data use, it is phase linear.

The phase linearity means that, throughout the frequency range the delay introduced by the filter is constant. So, that all frequencies are treated equally. If this were not the case, data signals could be damaged within the filtering process. Although FIR filters are the simplest type of digital filters to implement, they do demand quite a bit of computing power, as the filtering process involves a

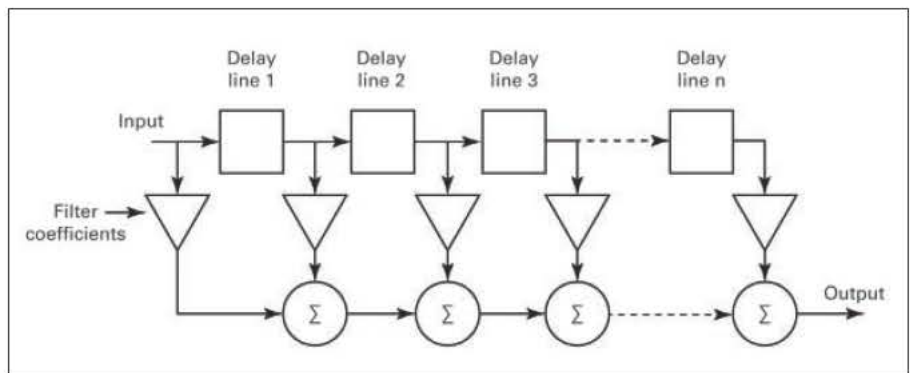


Fig. 1: Finite Impulse Response (FIR) Filter block diagram.

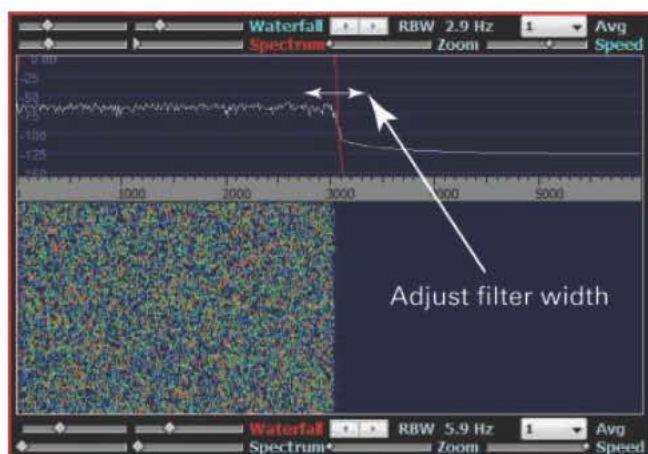


Fig 2: Adjusting the filter width in HSDR.

rapidly repeating calculation

One of the joys of modern digital filtering is the way in which the filter characteristics can be defined and changed visually, merely by dragging the filter shape in the spectrum display, as shown in Fig. 2 when using the *HSDR* program. This is an incredibly powerful tool that allows you to customise the filter to match the prevailing listening conditions. There have been many times when I've just squeezed the response to exclude an interfering station whilst leaving as much of the wanted signal as possible.

In some SDR software you will find that you also have the option to alter the filter length or number of 'taps'. This adjustment needs to be treated with caution as any increase in filter length will rapidly soak-up processor capacity. Applying too long a filter length may cause your PC to freeze. As it can also

introduce distortion into the signal or even cause other unpredictable results.

If you have a powerful PC and feel the need to improve the filter performance you can increase the tap size but you do need to watch the impact carefully. Conversely if your PC is struggling with your SDR software – you can lighten the load by decreasing the filter length.

Additionally, with the ability to customise the receive bandwidth, most SDR receivers include some very powerful notch filters that can be 'dropped into' the receive passband. On the Excalibur Pro receiver package, there are two notch filters available, each of which can be adjusted for both centre frequency and filter width. These notch filters generally have very steep sides and are able to take-out interfering carriers with minimal effect on the wanted signal.

Signal Identification

As I've mentioned previously, SDR receivers introduce a new way of viewing and tuning into the radio spectrum. To make the most of this new flexibility we need to develop some new monitoring skills. Most experienced Amateurs are able to recognise a wide range of modes, simply by listening to the sound they make as you tune across them with a conventional tuning system.

Tuning the band and listening, all changes with SDR, as you can often see most of the required band at a glance on the spectrum display. It's generally not usual, to tune across the band in the same way you would with a conventional receiver.

When using an SDR receiver system, the normal tuning method is to 'click-tune', a method in which, you see a signal of interest and you click, with the mouse, on the spectrum display to cause the software to 'tune' to that signal. That may be then followed-up by fine tuning in a number of ways.

One method of fine tuning, is accomplished, by clicking-hold and drag the tuning point to complete the fine tune. Some operators may prefer to use the simulated tuning knob or arrow buttons for fine tuning, which are often present in some software.

To make the best use of this new and very rapid tuning system, we need to be able to recognise signals from the patterns they make on the spectrum or waterfall displays. In my experience, it's the waterfall display that provides the most useful information for signal identification. The key to identification lays in understanding the modulation used for the different signals.

Voice Signals

Perhaps the easiest signals to spot are Amplitude Modulated signals (a.m.), as these comprise a central carrier with information sidebands on either side. On the spectrum analyser this type of signal shows as a steady, central peak with rapidly varying and matching sidebands on each side. Within the waterfall display, a.m. is even more obvious, as it shows a solid line for the carrier and less distinct but matching sidebands on each side.

The screen shot in **Fig. 3** shows a commercial broadcast station transmitting piano music. In the waterfall you will see that there are distinct traces that look a bit like shooting stars. These are individual piano notes that start loud when struck by the hammer but then fade, hence the diminishing trace.

Conversely, **Fig. 4** shows a commercial broadcast station transmitting speech only and here you

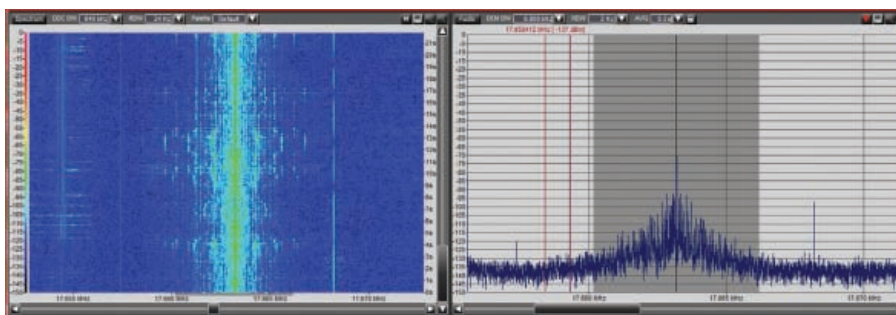


Fig. 3: An a.m. signal broadcasting piano music.

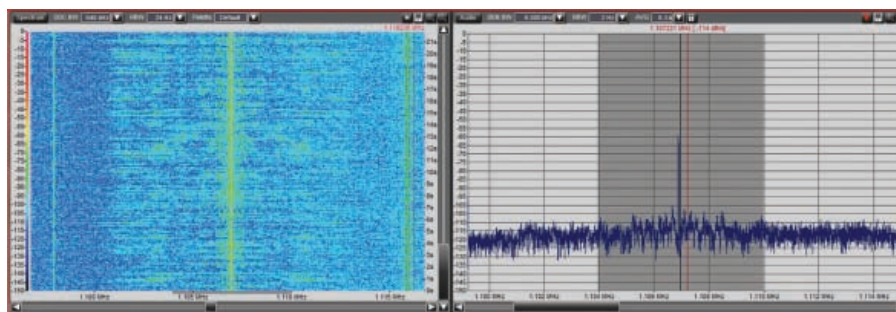


Fig. 4: An a.m. signal during a speech broadcast session.

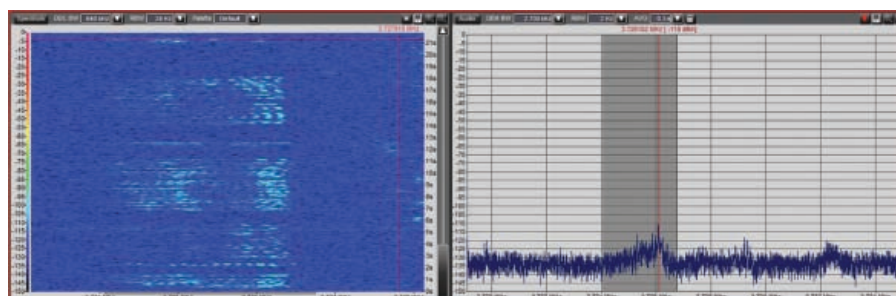


Fig. 5: An Amateur s.s.b. voice transmission.

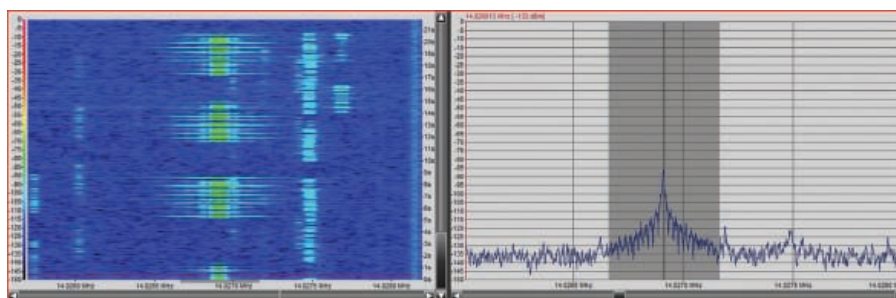


Fig. 6: An Amateur Radio c.w. signal.

can see that the central carrier remains very clear but the sidebands are far less distinct. Frequency modulation signals (f.m.) look very similar to a.m. on both the spectrum analyser and the waterfall displays. The central carrier shows up quite distinctly and the sidebands are indistinct in much the same way as for a.m. signals.

The lack of clarity is not generally a problem because both a.m. and f.m. tend to be used in totally different parts of the spectrum so you usually know what to expect.

For Amateur Radio use the most common speech signals on the h.f. bands are single side band signals (s.s.b.). The full definition of course is single sideband, suppressed carrier

which means that these signals are essentially an a.m. signal but with the carrier and one of the sidebands removed.

Looking back at the trace for a.m. signals it is easy to predict that the s.s.b. signal should contain a single rather indistinct sideband. The signal in **Fig. 5** shows a typical amateur s.s.b. transmission with the indistinct or 'smudged' look within the waterfall display. Although this may at first seem rather vague the smudged look is a really strong characteristic of s.s.b. signals making them quite easy to spot on a waterfall display.

Although the smudged look is useful, to identify an s.s.b. signals, the spectrum display may be less helpful in this case.

It would be very easy to miss signals if you relied on that characteristic alone.

When tuning an s.s.b. signal you need to click in the spot where the carrier would be, if it hadn't been suppressed. That means clicking slightly to the left for u.s.b. and to the right for l.s.b. Signals. Choosing the correct point is a matter of experience and with a bit of practice you will soon learn the correct tuning point for your system.

Additionally, while using the spectrum and waterfall displays to identify signals, you can also use these as measurement tools to check the quality of the transmissions themselves. Using these tools it is very easy to spot any splatter from an overdriven power amplifier.

Data Signals

The most basic of data signals is of course Morse code or c.w. And this is generally very easy to spot on the waterfall display as you can usually see the transmission breaks between Morse elements as shown in Fig. 6. As well as being able to identify the signal, again you can use the tools to check transmission quality. You will see from Fig. 6 that the signal here has some wide-band 'spikes' associated with the signal; these are key clicks.

After the simple On/Off of c.w., the next most popular data mode on the h.f. bands is probably PSK31 and I've shown traces of PSK31 on the 14MHz band in Fig. 7. In this case you can see that the spectrum display is not at all helpful in mode recognition but the waterfall tells a much more interesting story.

In the screen shot of Fig 7, you can clearly see the two-tone signal that precedes each transmission looking like a pair of horns and this also appears again briefly at the end of the transmission. At this stage, all we know is that this is probably a PSK signal but we don't know if it's PSK31, PSK63 or even PSK125.

However, we can verify this by measuring the bandwidth of the signal which should be approximately 31Hz, 63Hz and 125Hz respectively. The method of measuring the bandwidth will vary depending on the software you are running. The easiest way is to use the markers that are provided by many SDR programs.

To use the markers, they should be placed in the centre of each horn of the PSK signal and the bandwidth measured by calculating the difference between the two markers. With some receivers you can set one marker as the reference and all subsequent markers will show their actual frequency

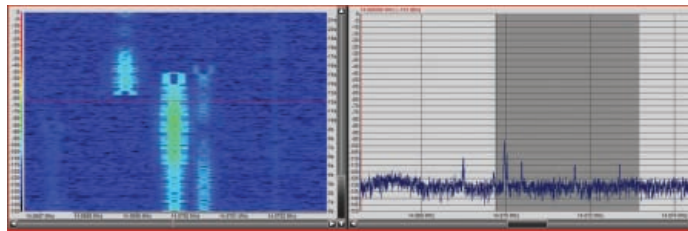


Fig. 7: An Amateur Radio PSK31 signal.

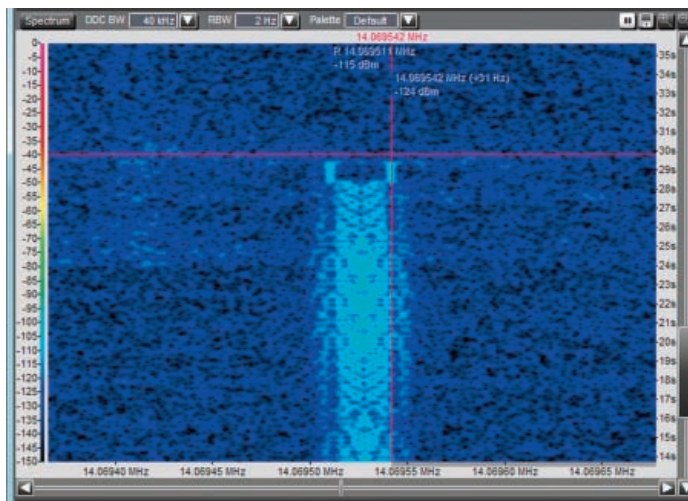


Fig. 8: Measuring a PSK signal with the Excalibur Pro.

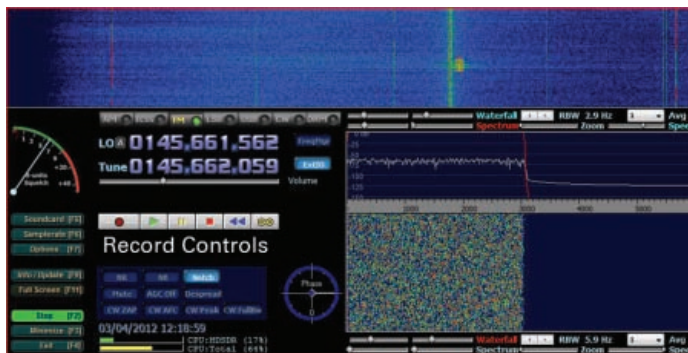


Fig. 9: HSDR - IQ recording and playback controls

and, more importantly, the difference between the marker frequency and the reference. This makes bandwidth measurement a breeze.

Analysis Techniques For SDR

Having just started on signal analysis we need to take a more detailed look at the analysis facilities provided by using SDR receivers, as we will be making extensive use of these facilities as we progress. From the examples I've covered so far you will have noticed that the waterfall display reveals more about signals than the spectrum display.

However, before we can perform any detailed analysis we ideally need a clean copy of the signal that remains steady long enough for us to make our measurements. This is where SDR receivers excel. One of the simplest ways to achieve this is to pause the waterfall display.

The method of pausing will vary from receiver to receiver but in HSDR you simply stop the receiver and the displays freeze but you will still be able to move the cursor and take measurements. In

Excalibur Pro the waterfall display has its own pause button along with the facility to scroll back through the past 99 seconds of received signal.

The pause and replay function is extremely useful, as you can scroll through the signal to find the cleanest example and make your measurements at that point. In Fig. 8, I've shown an example of a PSK31 signal being measured in Excalibur Pro. An alternative technique is to make a recording of the received spectrum.

Virtually all SDR receivers include a recording facility and it's a significant help for signal analysis. The recording captures the raw IQ signals so, that on playback, you can process the signal as if you were receiving it for the first time.

When looking at the recorded signals, you can adjust filtering, demodulation and all the other controls to help isolate the signal before starting your measurements. And if you feel it's not quite right – you can try again!

That's all I have time for this month so next time I will continue with a few more tips. ●