Mike Richards reviews the latest receiver from WiNRADiO

Mike Richards takes a look at the WiNRADiO G39DDC Excelsior, a receiver that some might consider to the best software defined radio currently available.

WiNRADiO G39DDC Excelsior

If there's one thing that is likely to be at the top of a radio enthusiast's wish list, it's a system that can find signals quickly. The WiNRADiO G39DDC Excelsior certainly has the ability to do this and it must be something close to a dream receiver.

The receiver's frequency coverage extends from 20kHz through to 3.5GHz and the search speed is 1GHz per second – yes, that really is a full 1GHz of spectrum every second, now that really is fast! With that sort of speed, you can catch just about any transmission on a given band of frequencies.

In addition to ultrafast searching, the WiNRADiO G39DDC Excelsior uses the latest in software defined radio (SDR) techniques to provide a dual channel receiver with a sensitivity of 0.11µV on single sideband (SSB) and a tuning stability of 0.5 parts per million (ppm) throughout its operating range. The receive bandwidth is also continuously adjustable down to 1Hz!

As you can probably guess, this receiver has been designed for use by government agencies and other professional spectrum monitoring groups. The price tag, approximately £5,000, might seem expensive but in professional monitoring circles, the WiNRADiO G39DDC Excelsior is a bargain.

Package and Connections

The G39DDC Excelsior follows a similar construction to other receivers in the WiNRADiO range, comprising a cast aluminium case that's shrouded in clear plastic. However, the high performance G39DDC Excelsior also has an external heat sink along with a miniature fan to keep the hard working electronics under control.

Connections are very simple, with a multi-pin socket for the USB lead, an SMA socket for the antenna and a coaxial power connection – making the WiNRADiO G39DDC Excelsior very much a black-box receiver.

The power requirement is 12V at 1.5A and a low noise switched mode supply is included.

The dedicated G39DDC Excelsior software is supplied on CD-ROM and as with many specialist USB devices, it's important to load the software before you plug in the receiver. Once the software is loaded, you can power up and plug in the receiver and Windows will automatically locate and install the appropriate receiver drivers.

Specifications

Frequency Range	20kHz to 3.5GHz
Receiver Type	Dual DDC SDR with up converter superheterodyne front end
Intermediate Frequencies	HF: 70MHz, VHF/UHF: 3.91GHz and 70MHz
A/D Converter	100 Mega samples per second, 16-bits per sample
Spectrum Analyser	Real time, 16MHz wide
Recording & Processing bandwidth	4MHz
Filter Bandwidth	Continuously variable down to 1Hz
Receive channels	Two independent receivers
Recording	IF and Audio with pre-buffering
Sensitivity	0.11µV SSB, 0.05µV CW
Tuning Stability	0.5ppm
Search speed	1GHz per second
Scan Speed	80,000 channels per second (12.5kHz spacing)

Third Generation SDR

The deceptively compact case of the G39DDC Excelsior contains the hardware required for a very sophisticated receive system. Let's start with a brief introduction to modern SDR receivers.

Early SDR implementations employed conventional RF front ends to bring the required signals down to a workable intermediate frequency (IF) where initial bandwidth filtering would be applied. At that point, the signal would then be applied to a special mixer circuit that would create audio frequency in phase and quadrature (IQ) signals. These audio signals were passed to the computer sound card for digitisation and software demodulation.

The creation of IQ signals is vital to the demodulation process and can be thought of rather like 3D for radio signals. In much the same way as two close spaced cameras allow 3D images, IQ signals enable the digital demodulation of just about any system. In 3D, the cameras are spaced apart, which introduces phase differences between the two signals and it's this difference that enables the creation of a more realistic view.

A similar potential exists in radio signals but in this case, we shift one signal by 90 degrees (known as quadrature, hence the Q). This simple change is all that is required to facilitate software demodulation of just about any transmission mode and it is at the heart of all SDR systems.

As the capabilities of analogue to digital converters (ADC) have increased, the digital section of SDR receivers has been moving ever closer to the antenna. WiNRADiO has adopted this approach throughout its G3 series of receivers, including the very popular Excalibur and the professional G315 series.

These third generation SDRs either digitise the entire spectrum in the case of an HF receiver or digitise a high frequency IF. While modern ADCs can easily digitise a 30 or 40MHz bandwidth, a problem arises when it comes to processing the high-speed output of the ADC. Let's look at an example of an ADC sampling at 100 million samples per second (as in the G39DDC Excelsior).

It is common practice to take 16-bit samples so each sample comprises 16-bits of serial data. If we then multiply that by 100 million samples per second, we get a data rate of 1,600,000,000 bits per second – that's 1.6 Giga bits per second, way faster than any of the usual serial communications systems can handle and there's not a hope of demodulating the signal using a standard home computer.

The solution is to add some further digital processing known as decimation or digital down conversion (DDC) that takes slices of the spectrum and converts them to a much more manageable data rate. The device used to achieve this is a field programmable gate array (FPGA). This is essentially a very high speed chip that's packed with configurable gates. The FPGA used in the G39DDC Excelsior contains 24,624 logic elements, 66 memory blocks, 608,256 bits of RAM, 66 multipliers, 4 phase-locked loops and 215 programmable inputs or outputs!

Block Diagrams

In the accompanying block diagrams, **Fig. 1** shows the analogue front ends that contain two separate sections for HF and VHF/UHF.

To help control out-of-band signals, the VHF/UHF section employs a bank of seven band pass preselectors that are followed by a selectable gain preamplifier and then a dual conversion process with two digitally controlled oscillators/mixer combinations and a 30MHz bandwidth IF amplifier. The output is a 16MHz wide 70MHz IF signal.

The HF front end is somewhat simpler with a 50MHz low pass filter, a switchable attenuator, a preamplifier and a digitally controlled oscillator/mixer to create a similar 16MHz wide, 70MHz IF signal. The 70MHz IF is then amplified and filtered before being passed to the analogue to digital converter.

The G39DDC Excelsior ADC runs at 100 million samples per second, which is more than enough to handle the 16MHz bandwidth of the 70MHz IF signal.

As you can see from **Fig. 2**, the G39DDC Excelsior uses the FPGA to create two independent receive channels plus a 16MHz wide spectrum sampler. Each of the two receivers employs two cascaded DDCs and the outputs of both are available for the PC – more on this later.

The internal PCi card version of the G39DDC Excelsior communicates directly with the PC bus but the external G39DDCe employs a USB-2 interface for the digital signals. The functionality is the same for both versions except that the output of the DDC1 for the second receiver is limited to 2MHz bandwidth due to the limitations of the USB-2 interface.

In addition to providing the raw power to down convert and process the 70MHz IF signals, the G39DDC Excelsior hardware supports the ultrafast tuning and scanning rates that make this such a powerful receiver.

Operation

The G39DDC Excelsior software follows the same styling as other products in the WiNRADiO range and it is very easy to navigate because most of the features are self-explanatory.

As you can see from the screenshot (**Fig. 3**), the main screen has three prime display areas. The two top panels are used to show the DDC1 and DDC2 spectrums whilst the larger lower panel is used for the specialist spectrum and activity analysis features.

As I mentioned earlier, each of the receivers uses two DDCs, the first of which can be set to handle a segment of

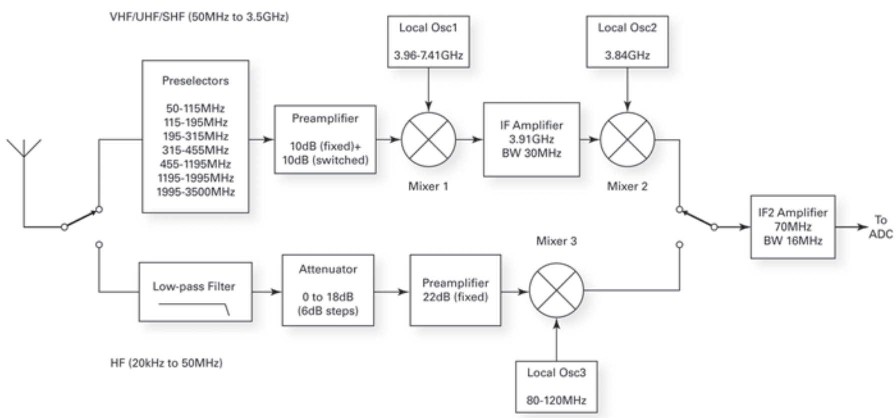

Fig. 1: The Excelsior's RF sections.

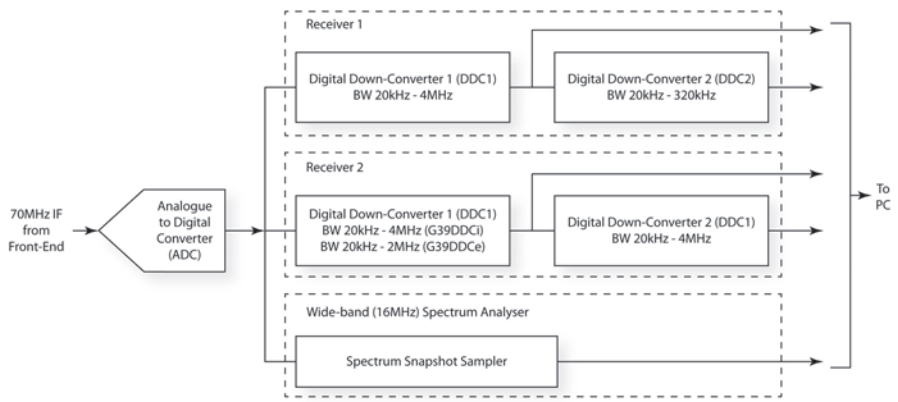

Fig. 2: The Excelsior's digital sections.

between 20kHz and 4MHz wide and the second from 20kHz to 320kHz wide. This might seem a bit odd at first but those displays are extremely useful.

In a typical monitoring set up you would arrange the wide 16MHz spectrum analyser so that it spans the band in question and then set the DDC1 with a relatively high bandwidth of say 1 or 2MHz and DDC2 with a much narrower bandwidth of maybe 40kHz. With the receiver set up in this way, you can watch the 16MHz analyser for signals of interest and then simply click on them to automatically retune the receiver to that frequency. You can then use the DDC1 and DDC2 displays to see a more detailed spectrum analysis and carry out fine tuning. This is a quick way to locate and tune to any interesting signals. Tuning on all three displays is by simple point and click so you can cover a huge range of frequencies in no time at all.

In addition to providing rapid tuning and demodulation, each display includes detailed measurement facilities so you can accurately check frequencies, signal levels and spacing. The measurements are based around the use of markers that are placed via the right click menu. You can add as many markers as you like and it is possible to set one as the reference marker, in which case the other markers automatically reported their frequency difference from the master. This is particularly useful for signal analysis.

One of the most powerful features is the lower display that spans the entire width of the window. In its default state, this provides a spectrum analysis of the 16MHz wide IF signal and supports click-to-tune, as with the other displays.

The display can be switched between a standard spectrum analysis and a waterfall, which can often be the more revealing. In addition to these two basic modes, there are very powerful sweeper and activity monitors. Both of these can be set to cover any bandwidth and their prime use is to identify signal activity. For example, to monitor the civil airband, you set the sweeper to sweep from 118 to 136MHz and all the activity is immediately visible. This is because this relatively narrow band is scanned about fifty times per second! The activity monitor adds a level of sophistication by including a pre-settable signal threshold. When running, the activity monitor keeps a note of any signals that exceed the threshold (hits) and these can be reviewed, tuned in or transferred to the memory system.

Remember, both these modes search at 1GHz per second so you won't miss much!

Frequency resolution of all displays at all frequencies is to 1Hz so you can easily make detailed signal measurements. Each of the DDC display areas feature parameter adjustment where you can adjust the receive bandwidth, averaging, peak hold and so on, although you should be careful with these settings because sharp filtering and wide DDC1 bandwidths can increase the processor load considerably. For most situations, the default settings represent a very good starting point.

One of the special features of DDC1 is its ability to show a waterfall representation of the spectrum. This is particularly helpful as the ever-changing spectrum display is replaced by a gently scrolling display where each signal is shown by a vertical line. This is excellent for spotting weak but consistent signals and for detecting speech contacts because the breaks between overs show as dotted lines.

Moving on to DDC2, here the display options are to switch between the RF spectrum that's presented to the demodulator or to show the recovered audio. Both can be very useful.

With all the displays, there is the facility to zoom in for a closer look and to save a bitmap image of the current spectrum display.

Spectrum Recording

For serious analysis work, the entire spectrum handled by DDC1 can be recorded to disk – that's up to 4MHz in the case of the internal PCi card version of the G39DDC Excelsior. This recording enables the continual replay and analysis of a signal or group of signals.

DDC2 also includes a record facility but in this case it is the recovered audio that's stored as a Wave file. The recording is controlled by the receiver squelch so it can be left on a channel that is only used intermittently and it will automatically capture all the traffic and ignore the gaps.

Receiver Controls

At the top of the display is a fairly conventional control panel for each of the receivers with a tab to switch between receiver 1 and 2. The control panel includes a tuning knob and a frequency display as well as the decoder controls. The S-meter is calibrated and displays dBm, µV or S-units and includes peak, root mean square (RMS) or average weighting. Receive mode selection is via a series of tabs at the top of this section and include amplitude modulation (AM), synchronous AM (AMS), upper and lower sideband (USB and LSB), double sideband (DSB), independent sideband (ISB), Morse (CW), FM, wide FM (FMW), Digital Radio Mondiale (DRM), frequency shift keying (FSK) and a user defined mode. This latter mode allows setting and saving a customised combination of modes and bandwidths that could then be reloaded quickly.

As you would expect from an SDR receiver, there were a host of customisation controls for just about all aspects of the receiver. The filtering is superb and can be adjusted from 1Hz upwards in steps of 1Hz. The filters sides were very steep and could easily split a radio teletype (RTTY) signal so you could only hear one tone. The filters can be adjusted either by dragging the bandwidth markers on the display or by altering the numeric settings directly. There's also the facility to increase the filter length to give even steeper sides but this needs to be adjusted with care as long tap filters eat processor capacity.

All the demodulator tools are very well specified and simple to use and included notch filters, squelch, gain adjustment and noise blankers.

The audio section even includes a pause button that can be used to temporarily suspend decoding and store the received spectrum to disk. This is useful because it gives you time to set up a decoder when a new signal appeares so you can capture the entire signal.

For professional users, there is an integral option to hand off to a separate WiNRADiO G315 narrow band receiver for specific signal monitoring. This automatically transfers all the tuning and demodulation settings of the G39DDC Excelsior to the G315 so that specialised monitoring can take place.

In Use

Once I'd familiarised myself with the G39DDC Excelsior, it was a real delight to use and I found it was an incredibly powerful monitoring tool. One area that's always difficult to monitor is the military airband because it's nearly 200MHz wide and often has only a small number of active stations, each of which make very short duration transmissions. Conventional scanners are often too slow and it's pot luck if they hit upon an active channel.

The G39DDC Excelsior makes this a very simple task because you can use the sweeper or activity monitor to repeatedly scan the entire band for activity. With a search rate of 1GHz per second, it can whip across the entire military airband at just over five times per second so you don't miss a thing!

The activity scanner is particularly useful here because once you've captured a list of hits, you can put these into the G39DDC Excelsior's memories and run a conventional scan to separate the active channels from the spurious signals.

When examining an active band such as the marine or civil airbands, I found the waterfall display to be particularly helpful. With a 16MHz spread, it's wide enough for most band segments and the waterfall makes active signals so easy to spot. For a half-duplex conversation, you see a dashed line on the display to differentiate it from any permanent signals – see **Fig. 4**.

Although I spent most of my time chasing around the VHF/UHF bands, the G39DDC Excelsior is also a very capable HF receiver and it can comfortably handle signals throughout its 20kHz to 3.5GHz range.

The challenges on HF are very different and the separate HF front end certainly worked well. As well as the usual range of utility signal monitoring, I also tried the G39DDC Excelsior during a very busy amateur SSB contest and it handled this very well. The superb filtering made it very easy to separate out signals and the recovered audio quality was excellent.

I also used the G39DDC Excelsior to monitor short and medium wave broadcast stations and again it performed extremely well and I especially liked the synchronous AM demodulator. This locked on very quickly and produced excellent audio quality. The infinitely adjustable filters and visual displays were especially useful for broadcast work because I could clearly see the interfering signals and adjust the bandwidth and notch filters to suit (**Fig. 5**).

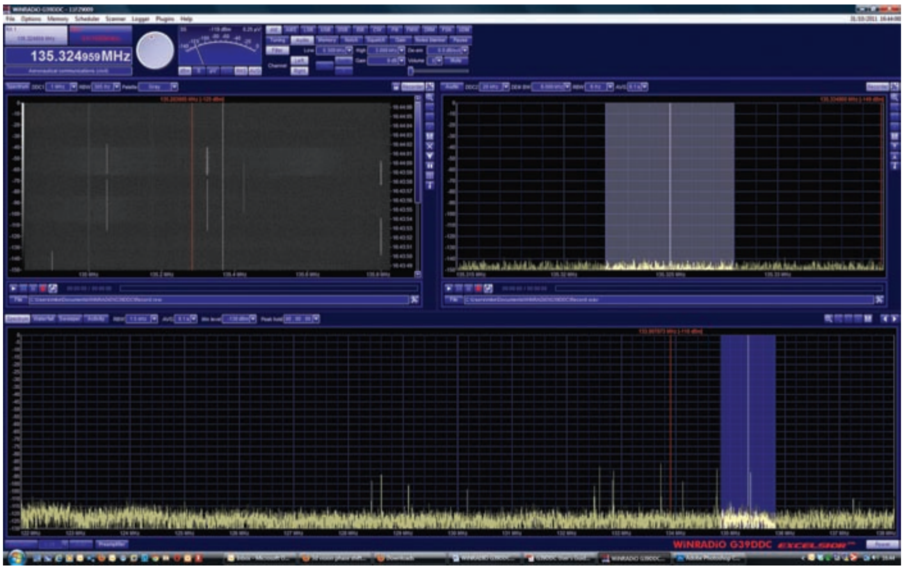

Fig. 3: Analysis of the civil airband segment.

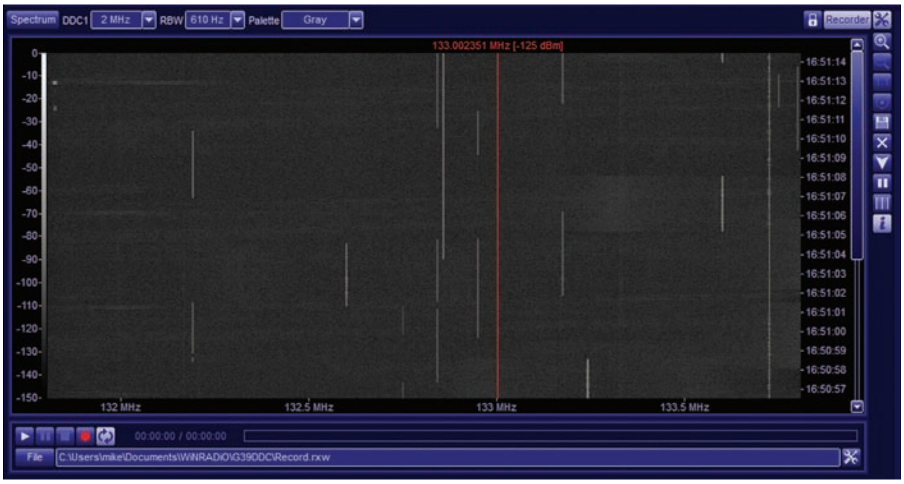

Fig. 4: Analysis of the waterfall display can aid identification of half-duplex activity.

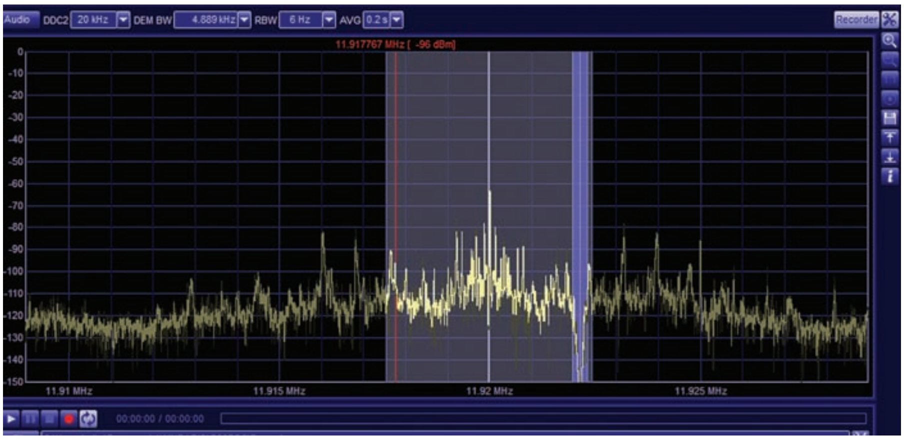

Fig. 5: A notch filter applied while receiving an AM broadcast station.

summary

As I'm sure you've gathered by now, the WiNRADiO G39DDC Excelsior is a stunning receiver and a dream for radio enthusiasts. Although this is a fairly lengthy review, I have only really covered the most interesting aspects of its performance and I've not even touched on the memory system, scheduler and the extensible radio specification (XRS) plug-ins that can be added.

The ability to examine and record huge chunks of spectrum with such ease is a delight and is matched by the WiNRADiO G39DDC Excelsior's creditable narrow band performance.

It's no surprise to hear that it is selling well in its commercial marketplace because it is undoubtedly a very powerful surveillance tool. This level of performance comes at a price of course and the Excelsior, as reviewed here, is available directly from Radixon and costs approximately £5,000. My thanks go to Radixon for the loan of the review model. ●