WiNRADiO WR-G31DDC Excalibur Receiver

A direct digital sampling receiver for use up to 50MHz

PHOTO 1: The Excalibur receiver hardware is contained in a small shielded box inside a clear plastic case.

INTRODUCTION. WiNRADiO have been developing and manufacturing PC controlled receivers and receiver systems since 1996. An Australian company supplying professional, government and hobby markets, they have an extensive product range and are one of the leaders in software defined receivers. Their latest model is the WR-G31DDC Excalibur, a direct digital sampling receiver for use up to 50MHz. Boasting a high performance specification, I was keen to check it out to see how well it performed.

RECEIVER HARDWARE. The Excalibur receiver hardware is contained in a small shielded box inside a clear plastic case. Interfacing to a PC is via USB2 and the receiver is powered from an external 12V supply. Linear-mode power supplies are preferable and a small 800mA unit is provided with the receiver. A somewhat unconventional USB connector is fitted but fortunately a connecting lead is provided. The antenna connector is SMA but an adaptor to BNC is also provided. The only control on the box is a power on-off switch and a blue LED indicator is fitted that flashes in various sequences to indicate USB interface status.

The latest software defined receivers, such as the Excalibur, are tending to use direct digital conversion and this avoids the image and harmonic responses inherent in the QSD analogue down-conversion approach. The Excalibur uses a 16-bit A to D converter sampled at 100MS/s and covers the frequency range from 9kHz to a little under 50MHz. This is followed by the FPGA digital downconverter (DDC) that reduces the data transfer rate to the PC to a level that the USB2 port and PC can handle. The DDC selects a slice of the input spectrum between 20kHz and 2MHz in width by a process of decimation and this DDC spectrum is passed to the PC for all further processing. Within the PC a further stage of decimation reduces the spectrum width to a few tens of kHz, the demodulator spectrum width (analogous to the final IF in analogue receivers), where channel filtering and demodulation is performed.

A sharp cut-off filter at 50MHz is fitted in the path to the A to D converter to suppress the image that appears between 50 and 100MHz as aliasing from the 100MHz sampling process as well as further images higher in frequency. A 1.8MHz high pass filter may be selected to prevent overload from medium wave signals. No other filtering is fitted; the feed to the A to D converter is wideband to 50MHz. This may be regarded as a recipe for strong signal problems but in reality the A to D converter has sufficient dynamic range to make this unnecessary, and small filters with small cored inductors are themselves prone to strong signal distortion effects. An input attenuator from 0 to 21dB in 3dB steps is provided and a front end amplifier to improve sensitivity is in-circuit continuously.

Inside the box, the receiver is contained on two printed circuit boards. One board contains all the components except the front end, with the key areas well shielded. The other board contains the front end components.

INSTALLATION AND SOFTWARE. Although the receiver is provided with a CDROM, I downloaded the latest software version and drivers from the WiNRADiO website. The software requires Windows XP, Vista or 7 operating systems and the installation process was straightforward and trouble free. WiNRADiO recommends a PC with 2GHz dual core CPU and 1GB RAM to make full use of the available features but it will run on a slower PC if the DDC bandwidth and filter sharpness settings are set to lower levels.

SOFTWARE FEATURES. The Excalibur is more than just a receiver; it is also a high performance spectrum analyser over a wide range of frequencies and a useable dynamic range in excess of 110dB. The user interface has been developed to enable easy access to all the features and provide effective control whether it is used as a normal receiver, an analytical receiver or spectrum analyser. The control panel continuously displays three spectrum scans. The full span of the receiver, either 50MHz or limited to 30MHz is shown in the lower part of the screen. The DDC spectrum is shown separately and the third display shows the demodulator spectrum or the audio spectrum. Point and click or mouse drag tuning operates on all three displays and multiple markers can be set. Display averaging, resolution bandwidth and baseline settings are features familiar to spectrum analyser users and all are implemented in the Excalibur. The wideband and DDC spectrum displays can also be set in waterfall mode, which is useful particularly to identify certain types of signals and signals that come and go with time.

Three receivers can be set within the DDC spectrum and these receivers are fully independent allowing separate modes, bandwidths and all other parameters with mixed or separated audio outputs (within the stereo limitation of two channels) and may be separately recorded to hard disc. Modes include USB, LSB, CW, AM, synchronous AM, FM and FSK. DRM is available with a suitable licence. FSK uses USB with a shifted passband and gives inverted RTTY according

PHOTO 2: The receiver main printed circuit board.

TABLE 1

Frequency Offset	Reciprocal mixing 2.4kHz bandwidth	Reciprocal mixing 500Hz bandwidth	Equivalent Phase noise
1kHz	99dB	106dB	-133dBc/Hz
2kHz	106dB	113dB	-140dBc/Hz
3kHz	111dB	118dB	-145dBc/Hz
5kHz	112dB	119dB	-146dBc/Hz
10kHz	111dB	118dB	-145dBc/Hz
15kHz	115dB	122dB	-149dBc/Hz
20kHz	117dB	124dB	-151dBc/Hz

TABLE 2

FILTER	BANDWIDTH					
LENGTH	-6dB	-60dB	-70dB	-80dB	-90dB	-100dB
200	2400Hz	3032Hz	3075Hz	3462Hz	4342Hz	5128Hz
5000	2400Hz	2425Hz	2430Hz	2513Hz	2741Hz	3407Hz

to the normally used LSB convention.

The radio can be tuned in many ways – point and click, spectrum drag, virtual tuning knob, keyboard arrow keys, mouse wheel tuning, direct frequency entry, digit tuning, channelised frequency stepping, memory recall and probably more that I did not discover. 1kHz steps are fundamental to many of these methods but 1Hz, 10Hz or 100Hz steps can be accessed with the ctrl, shift or alt keys pressed.

The channel filter bandwidth is adjustable over a vast range from 10Hz to 62.5kHz in 2Hz steps. Again there are several shortcuts and convenient ways of setting the bandwidth. The passband is shown on the spectrum displays and the position, edges and width can be dragged to provide IF shift, bandwidth and passband tuning functions. Filter length is a software processing function that determines the sharpness of the filter edges. The default setting is 200 but it can be adjusted over a wide range and at the highest setting of 5000 the shape factor is phenomenal. The highest settings do require a high CPU speed. A notch filter is included with adjustable frequency and width, and a noise blanker with adjustable threshold. An audio filter is provided with adjustable low and high cut and selectable de-emphasis. Again these are settable numerically, via drop-down boxes or by dragging the passband shape.

The S-meter is calibrated in dBm, μV or S-units and can be set to show the peak, RMS or average values. Strong signals that result in ADC clipping are indicated and the input attenuator switched in automatically if desired. A fully adjustable AGC system is provided with fast, medium and slow presets and three user presets. Attack and decay times are adjustable together with reference level and maximum gain. The AGC can be disabled and gain adjusted manually.

The memory capacity for storing and recalling frequencies is virtually limitless, determined only by the capacity of the hard drive. Names and notes are stored against memory items and the names are displayed when tuning close to the stored frequency. HFCC and EIBI broadcast databases freely available on the internet are also supported.

A built-in recording feature allows two different recording modes. The DDC spectrum can be recorded and played back later with all the receiver controls such as tuning, mode selection and bandwidth fully operational. It uses a considerable amount of hard disc space to record at the higher bandwidth settings. Alternatively the audio output from each of the three receivers can be recorded separately and simultaneously. Associated with the audio recorder is a comprehensive timer or scheduler that allows multiple recordings and repeat recordings at any time in the future.

Virtual Sound Card software is available from WiNRADiO at extra cost to pass the receiver digital audio directly to following applications such as data decoders without the need to pass through soundcards or audio cables.

MEASUREMENTS. Sensitivity measurements for 10dB S+N:N on USB in 2.4kHz bandwidth showed 0.4μV (-114dBm) across most of the tuning range, reducing substantially above 40MHz and below 100kHz. The medium wave filter introduced a 6dB loss at 1.8MHz but negligible loss at higher frequencies. AM sensitivity was typically 1.8μV (-102dBm) for 30% modulation depth and 6kHz bandwidth. ADC Dither is a mechanism within the converter to reduce spurious signals and if selected reduces sensitivity by raising the noise floor by 2dB to 6dB.

The signal strength meter calibration was excellent, within 1dB or so over the whole range of signal levels and frequencies and relates to the level at the antenna socket independent of the attenuator setting. S9 is 50μV and each S-unit is 6dB.

The rejection of spurious signals was dependent very much on level. Strong signals were exceptionally clean with spurii down 100dB or more. Lower level signals around S9 (-70dBm) resulted in spurii appearing as sidebands at about –120dBm. Other low level responses at about –120dBm could be eliminated by engaging dither in the ADC but not these sidebands. Sampling images at VHF were over 90dB down across the HF range, reducing rapidly above 40MHz.

No hole was observed in the AGC characteristic as seen with many DSP implementations. With software version 1.10, current at the time of this review (August), the AGC attack time was excessive (20 - 80ms), much slower than the set values. This resulted in attack distortion on SSB and CW modes. Radixon UK investigated this problem and released software version 1.13 with improved AGC. This measured close to the set values and a fastest attack time of 2-3ms in user settings.

Direct sampling SDR receivers respond in a completely different way to strong signals compared to analogue receivers and do not follow the 3dB/dB intermodulation rule. Intermodulation products are seen at a level of about –120dBm for input signals as low as –70dBm but do not increase substantially until the input signal levels are within about 3dB of the ADC clipping level. Unlike the Perseus receiver, ADC dither makes only a marginal improvement. The clipping level was reached with –3dBm input from a single signal or –9dBm from each of two equal signals as used for IMD testing. Signal handling collapses when the ADC clipping level is reached. When measured at the point where intermodulation starts to increase substantially, two-tone dynamic range measured around 106dB in 2.4kHz bandwidth or 110dB in 500Hz bandwidth and was independent of signal spacing. This equates to an analogue receiver with a 3rd order intercept of +36dBm. Once again the bar is raised on the highest close-in dynamic range I have ever measured. Spurious sidebands (see earlier paragraph) are likely to be more of an issue than intermodulation.

Reciprocal mixing measurements showed that the phase noise performance was excellent. Indeed, the figures are the best for any radio I have ever measured. However, there were some noise effects seen at much lower input levels around –70dBm for reasons unknown. The results are shown in **Table 1** measured at 16MHz using a low noise Wenzel oscillator source.

The excellent phase noise results enabled the channel filter skirts to be measured down to an incredible 100dB, a result I have never achieved before. The shape factors depend

PHOTO 3: The control panel continuously displays three spectrum scans.

on the filter length and are given in **Table 2** for the default setting of 200 and maximum length 5000 with the 2.4kHz bandwidth filter.

ON THE AIR PERFORMANCE. I liked very much the user interface, a good balance between ease of use and well presented information. The various spectrum displays were excellent and give a good visual impression of the radio environment. The main design focus of the radio appears to be AM broadcast for which it is excellent. Tuning with step sizes other than 1kHz, such as 10Hz or 100Hz on SSB, is a two handed process. It would be a big bonus if the fundamental tuning step size could be made selectable or mode specific.

The audio quality was generally very good, particularly so on AM. On SSB and CW signals, selecting an audio filter bandwidth a little wider than the channel (demodulator) bandwidth gave best results. With software v.1.10 distortion due to AGC attack was apparent but the later v.1.13 resolved this problem. The latest software version is readily downloadable from the WiNRADIO website. Best results on SSB/CW were achieved with a user AGC setting of 1ms attack and 2s decay times. Overall signal handling was excellent and the receiver was clean and sensitive. The channel filter features were excellent and easy to use and the notch was effective particularly on wider modes but difficult to tune on SSB. The LF time code transmissions were very well received, a good indication of low phase noise and a clean receiver.

The performance as a spectrum analyser was first class, with better resolution, wider display range and faster sweeps than my 100dB display range Hewlett Packard instrument.

CONCLUSIONS. The Excalibur receiver is a top rate performer supported by excellent software and the spectrum displays are a superb bonus. The 16-bit analogue to digital converter results in unsurpassed strong signal performance and once again my league table of close-in dynamic range receiver performance has a new No. 1. However, this must be tempered by the spurii seen with lower level signals, albeit at a weak level. The current price is around £650.

My thanks to Radixon and WiNRADiO for the loan of the receiver.

Both Waters & Stanton plc and Martin Lynch & Sons are authorised dealers for the WiNRADiO Excalibur, check out their adverts on pages 24 and 28 respectively for details.

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WR-G31DDC 'EXCALIBUR'

The WiNRADiO WR-G31DDC 'EXCALIBUR' is a high-performance, low-cost, direct-sampling, software-defined, shortwave receiver with a frequency range from 9kHz to 50MHz. It includes a real-time 50MHz-wide spectrum analyzer and 2MHz-wide instantaneous bandwidth available for recording, demodulation and further digital processing.

The receiver's superior performance results from its innovative, direct-sampling, digital down-converter architecture along with the use of leading-edge components and design concepts. These all result in a very high IP3, wide dynamic range, high sensitivity, and tuning accuracy. These key features create a receiver in a class of its own, with wide application potential, at a very affordable price.

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