WiNRADiO Excalibur G31DDC SDR Receiver

by Bob Grove, W8JHD

I grew up in the analog age. By age nine I was already playing with old tube-type radios, and by 13 I had my ham license. I cut my teeth on WWII surplus transmitters and receivers – anything with knobs to turn and meters to move.

By the time I reached adulthood, Asian-made radios began to trickle into the U.S. and pushbuttons replaced tuning knobs, prompting a whimsical question: "Don't the Japanese have thumbs?"

And then the final blow to my analog world – computers! My sons Bob and Bill grew up with these, wondering how I ever got along without them. I resisted getting a computer, even when I started Grove Enterprises in 1978.

But I finally capitulated and bought one for the office. It actually streamlined our operation. What a concept! Then I bought some more. "Hey, these things actually work!" I exclaimed.

When radios started getting "smarter," I was skeptical about digital control, but it's here. And with the emergence of the new WiNRADiO G31, I capitulate once again; the future of radio monitoring has arrived.

❖ Degrees of Digital: A Quick Tutorial

With the advent of the personal computer, digital technology has permeated the electronic communications industry. Receivers are now classed as either analog (the traditional architecture) or software defined.

Considerable debate has raged over just what must be digitized in a radio to make the claim that it is a software defined receiver (SDR). Early examples had simply the detector stage digitized; later on it included the intermediate frequencies (IF).

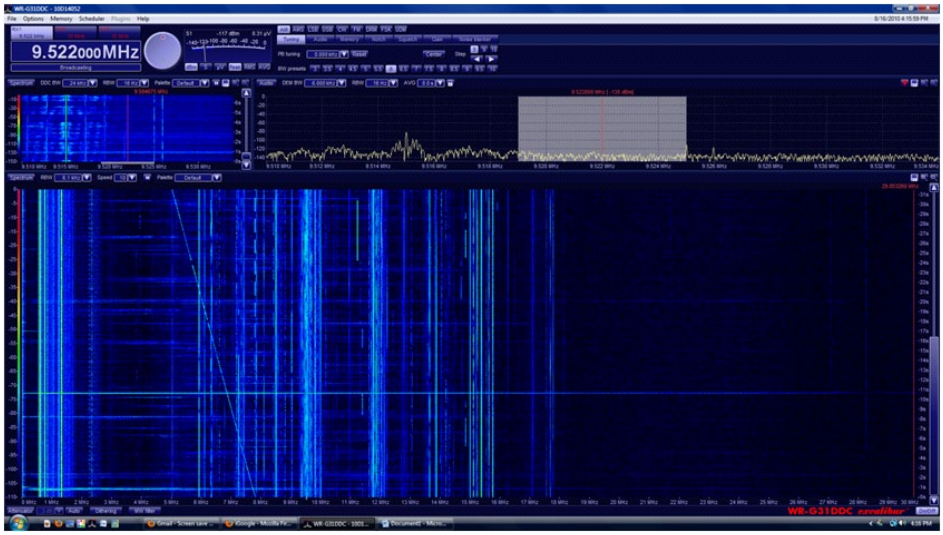
But WiNRADiO's new G31DDC Excalibur leaves little doubt it is a fully implemented SDR, since the only analog circuitry is in the RF preamplifier and audio output stages. All the rest of its signal processing is handled in a high level of fast Fourier transform (FFT) analog to digital (ADC) converters and field programmable gate arrays (FPGA).

With analog technology, the contents of a radio signal – frequency, amplitude, period, and modulation – are replicated as an electrical signal. In digital technology, there is no such mirror-like replication: The signal is sampled, parsed into myriad bits, and its contents become a single-amplitude, single-rate data stream.

But there's more to it than that. Once you purchase a conventional analog radio, what you see is what you get. With a software-defined receiver, improvements, refinements, additional features, and even functions can be changed or added via a simple software download.

❖ It's All in the Box

The entire receiver is encased in a sturdy, compact, die cast package the size of a paper-



The G31 waterfall spectrum for 0-30 MHZ left to right: Vertical lines are signals slowly scrolling upward to show changes over time. The diagonal trace is a frequency sweeper.

WINRADIO G31 EXCALIBUR SPECIFICATIONS

Design: Direct-sampling, digitally down-converting (DDC), software defined receiver (SDR)
Frequency Range: 9 kHz to 49.995 MHz
Tuning Resolution: 1 Hz
Modes: AM, AMS (AM Synchronous), LSB, USB, CW, FMN (FM narrow), FSK, UDM (User-Defined Mode), DRM (optional)
Image Rejection: 90 dB (typical)
Third Order Intermodulation (IP3): +31 dBm or better
Attenuator: 0 to 21 dB, adjustable in 3 dB steps
Spurious Free Dynamic Range (SFDR): 107 dB minimum
Noise Figure: 14 dB
Minimum Detectable Signal (MDS): -130 dBm at 10 MHz, 500 Hz BW
Phase Noise: -145 dBc/Hz at 10 kHz
Received Signal Strength Indicator (RSSI) Accuracy: 2 dB (typical).
Received Signal Strength Indicator (RSSI) Sensitivity: -140 dBm (0.02 uV)
Processing and Recording Digital Down Converting (DDC) Bandwidth: 20 kHz to 2 MHz in 21 selectable steps
Demodulation Bandwidth (Selectivity): 10 Hz to 62.5 kHz variable in 1 Hz steps
Spectrum Analyzers:
- Full spectrum/waterfall: 30 or 50 MHz span, 1.5 kHz resolution bandwidth
- DDC spectrum/waterfall: up to 2 MHz span, 1 Hz resolution bandwidth
- Channel spectrum: up to 62.5 kHz wide, 1 Hz resolution bandwidth
- Demodulated audio: 16 kHz wide, 1 Hz resolution bandwidth

Analog to Digital Conversion: 16 bit, 100 Mega Samples Per Second (MSPS)
Sensitivity (at 10 MHz):
- AM: -101 dBm (2.00 μV) at 10 dB S+N/N, 30% modulation
- SSB: -116 dBm (0.35 μV) at 10 dB S+N/N, 2.1 kHz bandwidth
- CW: -123 dBm (0.16 μV) at 10 dB S+N/N, 500 Hz bandwidth
- FM: -112 dBm (0.56 μV) at 12 dB SINAD, 3 kHz deviation, 12 kHz bandwidth

Audio Filter 300-3000 Hz, de-emphasis -6dB/octave
Tuning Accuracy: 0.5 ppm at 25 °C
Tuning Stability (0°-50° C.): 2.5 parts per million (ppm)
Medium Wave Stop-Band Filter:
- Cut-off frequency: 1.8 MHz at -3 dB
- Attenuation: 60 dB or greater at 0.5 MHz

Antenna Input Impedance: 50 ohm (SMA connector)
Output: 24-bit digitized I&Q signal, USB 2.0 high-speed interface
Power Required: 11-13 VDC at 500 mA (typical), 45 mA in power save mode
Operating Temperature: 0 to 50 °C
Dimensions: 3-3/4"W x 1-5/8"H x 6-1/2"D
Weight: 16 oz.

back novel, accessorized with a USB computer interface with matching cable; an SMA antenna connector (an SMA/BNC adapter is included); a DC jack (a 120VAC/12VDC adapter is also included); a push-button power switch; and an LED pilot light that doubles as a status indicator.

This new G31 Excalibur from WiNRADiO is a giant digital leap from a previous century of analog design. Covering a continuous 9 kHz (and lower) to 50 MHz spectrum, the screen for this receiver is an awesome display of numbers, graphs, and tables (admittedly, somewhat bewildering to the newcomer).

A highly accurate signal strength meter is included; it can be push-button selected to show S units, microvolts (uV) and dBm, and may be additionally contoured to show these units as peak values, RMS, or smoothed out for average.

❖ THREE Receivers!

Three tabs in the upper left screen invite selection of RX1, RX2 or RX3, which emulate the separate VCO/VFO settings in a conventional receiver. This feature allows you to set up three entirely different receivers with different functions which may be instantly selected anywhere in the 50 MHz receiver bandwidth.

In addition, you may hear the blended audio output of all three receivers at once, provided they are within a 2 MHz spread. For example, you may be waiting for an LSB ham transmission on 7212 kHz, an AM international broadcaster log-on at 7420 kHz, and an arriving airline USB station on 8918 kHz. There's no scanning delay: it's an instant capture of any of them, or even all three simultaneously!

For the game-playing computer guru, information-packed screens are familiar, but to the long-time, analog dial twister, it's a jaw dropper! It can become familiar, but it will take a while. Reading the accompanying instruction manual is mandatory.

All receiver functions are PC hosted. System requirements are quite conventional for modern computers: Windows XP, Vista, or 7, with a 2 GHz dual core CPU and 1 GB RAM. The display should be SVGA and only 20 MB hard drive space is required. A free USB port allows the connection, and audio is provided by your sound card.

User preference can be saved to disk, and spectrum display traces can be saved as BMP files as well.

The G31 will actually work with slower computers, but there will be some sacrifice in the sharpest selectivity and DDC bandwidth.

❖ Frequency Accuracy

With a built-in, temperature-compensated, crystal oscillator (TCXO) offering a stability of 2.5 parts per million, it's hardly necessary to calibrate your G31. But if you're a purist like I am, you can select a frequency of known precision like WWV, invoke the automatic calibration function, and touch the ENTER key to bring the oscillator even closer.

❖ Spectrum Displays

Dominating the screen are three spectrum displays – dynamic charts of the radio spectrum, constantly gyrating from the presence, frequencies, and relative amplitudes of signals. Unlike many competitive displays, the user can simultaneously listen to the signal as well as see it on the spectrum display, and can also drag the cursor across the screen at any speed like the tuning dial of a conventional receiver.

G31DDC screen showing full spectrum display (lower), 2 MHz span DDC display (upper left), and single-signal modulation waveform (upper right)

The bottom display – appropriately the largest display – shows all the signals present in the span of spectrum chosen by the operator, either 30 MHz for the familiar high frequency (HF or shortwave) portion of the spectrum, or the entire 50 MHz swath of the receiver's tuning range.

Being able to see the activity in the entire spectrum at once affords a number of advantages, including watching for activity and band openings so that one may immediately pounce on a signal anywhere in the spectrum with a click of the mouse.

The upper-left-hand display (DDC BW) allows the user to choose the chunk of digitally-down-converted spectrum to which he wants to pay particular attention, as narrow as 20 kHz or up to 2 MHz in bandwidth. The upper-right-hand display (DEM BW) allows the user to analyze the contents of any demodulated signal(s) up to 60 kHz bandwidth.

Want to see more signal detail on specific spikes or traces? Simply press and step the zoom icon for larger and larger magnification.

The display is in real time, with the received signal showing perhaps a 50-100 millisecond processing delay. The delay is so short it's hard to detect, unless you happen to have an analog receiver nearby receiving the same signal so that you can hear the echoic effect between the two. You can also *see* the slight delay as you watch excursions of the signal spike while monitoring the audio content of the signal.

Want to mark signal spikes you've already monitored? Simply press your right-hand mouse key. You can save any spectrum display by simply pressing the SAVE key.

❖ The Waterfall

Switch to this feature from the conventional spectrum display to reveal a colorful, mesmerizing, continuously-updated, scrolling panorama of all the signals in the 30 MHz HF spectrum or even full 50 MHz spectrum. Be sure to select the DEFAULT color palette – it's the prettiest!

The speed is adjustable to show up to ten continuous minutes of graphic data in full motion, and it can be recorded to disk for later playback and analysis. The scroll shows amplitude, modulation, on/off keying interval, frequencies and their shifts, interference, and other characteristics of the radio spectrum.

The waterfall adds a new dimension to monitoring as it reveals all band conditions and signals within its bandwidth over time. Strong signals register in orange to red, average signals in yellow and green, weak signals in blue. Watch band openings as weak signals begin to emerge on the dark palette background.

You'll see sweepers (ionosondes) as they register with diagonal lines, amplitude-modulated (AM) broadcasters with their delicately-fluctuated patterns, frequency shift keying (FSK) as side-shuttling lines, Morse code (CW) with its pulsed traces, and more.

And, just as with the spectrum display, you can zoom in on the waterfall as well.

Viewing the entire spectrum with the waterfall perspective is a transfixing, if not transcendental, experience. It reminds me of how I used to stare at the night sky with wonder, and how I admired photos of distant celestial objects – and then I got my own telescope and viewed infinity with awe! But don't watch it too long: take it from me, it's addictive!

❖ Tuning In

Selecting a signal frequency is easy and there's more than one way to do it. For precise frequency selection, simply type in the numbers, entering "k" or "m" for kilohertz or megahertz respectively. If the previous selection was already in the unit you want, just type in the numbers and hit ENTER.

The frequency display window reads out to 1 Hz, and the G31 is capable of this sort of tuning accuracy. A small window below the frequency display tells you the service authorization for that frequency (broadcasting, amateur radio,

G31 waterfall displays showing full spectrum users (lower) and modulation patterns on a smaller, magnified portion of the spectrum (upper).

maritime mobile, etc.).

There is also a graphic tuning dial; by resting the cursor there you can slew the dial up and down in frequency by pressing the left or right mouse button. Similarly, you can slew with your keyboard's up/down arrow keys, and fine tune by tapping or gliding the left/right on-screen tuning arrows or bar on the demodulator display.

Tuning steps are factory set at 1 kHz for general slewing, but can be set at 100 Hz with your ALT key, 10 Hz with your SHIFT key, or as fine as 1 Hz with your CTRL key. Especially useful for medium wave (MW) and shortwave (SW) broadcast tuning, you can select 5, 9 (European domestic), or 10 kHz steps by pressing on-screen buttons.

Detection modes are numerous: AM, synchronous AM, USB, LSB, CW, FM, FSK, UDM (user defined mode), and even DRM (Digital Radio Mondiale; French for digital radio worldwide, the international shortwave digital broadcast standard).

Because of the license cost to implement DRM, that mode is available only as an extra-cost option. The DRM works very well; it's the first time I've ever heard shortwave stations crisply, without fade, distortion, noise, static, or background hiss! DRM is not without fault, however; unstable band conditions can lead to frequent echo effects or even dropouts.

It may take up to ten seconds or so for the decoder to synch up with the received station. Even so, few stations are using DRM, so don't expect to be deluged with stations operating in that digital mode. It's popular in Europe, but North American listeners will be lucky to find one or two at the present time. [*For more on DRM see MT April, 2010 "Chasing DRM: the Elusive Dream of Digital Audio via Shortwave"- Ed.*]

While conventional factory-set parameters are invoked with each mode's selection, they can be independently altered to suit the requirements. The user defined mode (UDM) allows the operator to save special custom settings for a mode of his choice.

❖ Single-Signal Reception

Choosing the bandwidth necessary for pulling a signal out of the mire is an art, but it's easier when you can do it as you listen to it and can even see an impinging, adjacent-channel source of interference.

Selectivity options are simple, yet elegant. A gray shadow is placed over the frequency cursor; it follows a drag of the mouse key as you to stretch or compress the bandwidth, or even move the selectivity curve away from the center for the digital equivalent of IF shift (since direct digital conversion has no intermediate frequency). Alternatively, simply tap a preset bandwidth between 3 and 10 kHz from a screen chart.

A passband tuning feature is also provided which shifts both the center frequency and the filter bandwidth away from the offending interference signal. Since the filtering technology is digital, you can think of it as an endless series of filters which you can engage without any signal loss.

While it might seem the more filters the better, that takes husky processing which can slow down your computer. To choose an appropriate amount of filtering, the G31 panel has a load meter, and as long as you keep the load on the CPU below about 30%, filter to your heart's delight!

The RF notch filter is an amazing tool to squash adjacent-channel interference like a bug! Using a drop-down box, the user selects the frequency of the interfering signal and its bandwidth, hits "ENABLE," and it's gone! The spectrum display shows the graphic notch on the shadow so it can be trimmed to perfection. Try to do that with an analog radio!

❖ Powerful Recording

For decades, intelligence agencies like NSA have used high-tech receiving installations for "pre-detection recording"; that is, they could record and save for later playback and analysis all the signals in a particular part of the spectrum in actual time.

The G31 can do this, too, in any 2 MHz swatch of spectrum. Suppose you go away and want to hear the contents of a signal that you believe will come on the air between 6 and 8 MHz. Simply store that spectrum live on your hard drive for the time period in question, and when you return you can bring up the spectrum display screen and review what happened in those two megahertz while you were gone.

You can take your time while sampling one signal at a time, watching it on screen and demodulating its contents to hear. Massage the signal for best reception, and if the transmission stops, you can start it all over again.

Of course, as you become acquainted with the variety of functions, you're bound to screw it up. How do you ever get those settings back to where they were when you began? Easy – under OPTIONS, select RESTORE FACTORY DEFAULTS and you're there. And, I'll have to admit, the factory has made some pretty good decisions for their presets!

When you do actually arrange a pattern of functional selections you like that are different from the factory presets, you can save them in a memory file to call up again, even if you factory-reset the entire receiver.

❖ Audio Functions

Depending on your sound system, the audio characteristics of the received signal may be adjusted for low and high frequency cutoff, and de-emphasis (treble slope). A volume slider and up/down volume arrow keys are provided as well.

Of course, you don't have to switch to the audio screen every time you want to change the volume; just press or tap the left/right arrow keys on your keyboard.

A versatile squelch feature is a great help for listener fatigue, and the G31 does it with style. You can adjust the squelch level by signal strength, noise level, and voice presence. The three factors may be selected individually or in combination.

A flexible audio mixer allows up to three received signals to be monitored simultaneously in various combinations, including separate left and right ears for headphones or stereo speakers.

A mute key toggles the audio on and off, or you can simply switch the receiver off – it only takes one second to come back on.

❖ Using an Accessory Frequency Converter

If a VHF or UHF converter is used with the G31, a display offset feature allows the conversion frequency to be shown rather than the original receiver frequency. The frequency will track the receiver's tuning through the converter's operating bandwidth.

❖ Dealing with Interference

With a brawny third-order intermodulation factor of at least +31 dB, strong signal overload is unlikely, but should you have a local AM broadcaster with a whopping signal, you can activate the 1.8 MHz high-pass filter and watch the broadcast band virtually disappear.

For other high-power inundations anywhere in the 50 MHz worth of spectrum space, there is a variable-step attenuator you can select to suit the conditions.

❖ The Bottom Line

I'm sure my exuberance over this remarkable receiver is obvious. In my professional lifetime in communications electronics, I've never seen anything with such shortwave receiving and processing power at such a low price. In the time it took me to write this review, I have changed from a digital skeptic to a true believer. This is one amazing radio!

The new WiNRADiO G31DDC Excalibur is available from Grove Enterprises for $849.95.