Three Software Radios

By John Catalano

In this final part of our Software Definable Radio series, we have a surprise for you: instead of including the Yaesu FRG-100 in our comparison as promised last month, we have another new SDR which has just entered the market, RFSpace's SDR-14. Using the highly unscientific "Mark I eardrum" and lots of antenna switching, we will do some monitoring for real-time comparisons of FlexRadio Systems' SDR-1000, RFSpace's SDR-14, and one of the first computer-controlled receivers, ICOM's IC-PCR1000.

Let's start by introducing RFSpace's SDR-14 SDR and Spectrum Analyzer.

A Small Black Box

RFSpace recently introduced the SDR-14 to the market with these words, "The SDR-14 is a 14-bit software defined radio receiver. It offers a broad range of spectrum analyzer and demodulation capabilities. The hardware samples the whole 0-30 MHz band using a sampling rate of 66.667 MHz. The digital data from the ADC is processed into I and Q format using a direct digital converter (DDC). The I and Q data is then sent to the PC for processing using a USB 1.1 interface. All of the demodulation and spectral functions are done on the PC side."

The block diagram in Figure 1 clearly shows that, like FlexRadio's SDR-1000, the SDR-14 is a software defined radio with the amplified RF signal being fed into a fast analog to digital converter (A/D) without a heterodyne IF stage between it and the antenna! This configuration is defined as the **Ideal Software Radio** or ISR, a step up from the basic SDR concept. (*See sidebar definitions - ed*) Also notice the difference between the two software radios in the use of the PC's sound card by the SDR-1000. This processing is done internally by the SDR-14.

A direct input to the A/D converter is also provided which can be used to sample signals directly up to 200 MHz for use with downconverters. The SDR-14 can be used as a panoramic adapter by connecting this input to a communications receiver with an IF output, such as the ICOM R-71.

The included Windows software provides for demodulation of USB, LSB, AM, FM, WFM, CW, CWr and DSB. DRM is available via the use of third-party software (DREAM). The software also provides continuously adjustable filter bandwidths. Linux drivers are also available. The complete command structure is available so that anyone can write their own applications.

FlexRadio started this trend in early 2003 of providing completely open-source software. This allows any user complete access to all aspects, functions, algorithms and demodulation methods of the radio system, in contrast to manufacturers who do not provide access to their system source code and just allow users to interface with via "controlled" application modules. The analogy is similar to the difference between Windows and Linux. The Windows product is compiled software. It is an operating system that can be used and customized, but cannot be modified. Linux, on the other hand, allows the user full access to its operational source code/algorithms.

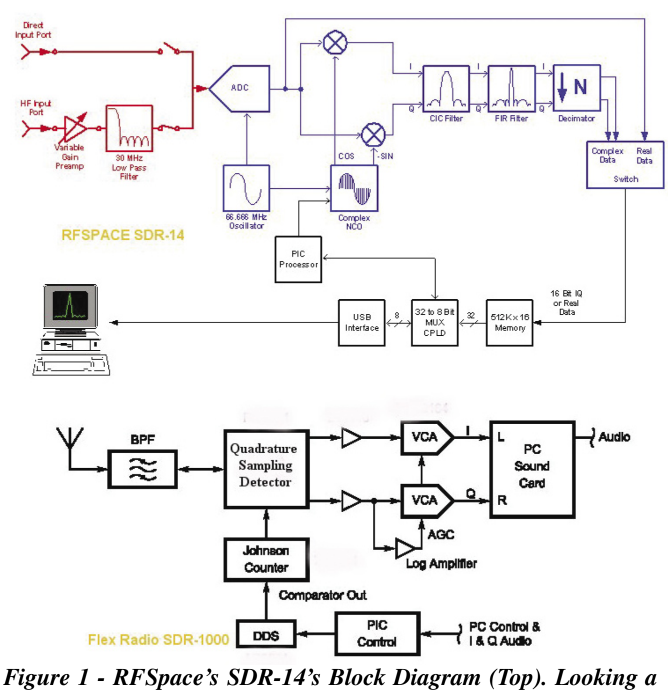

Figure 1 - RFSpace's SDR-14's Block Diagram (Top). Looking a lot like FlexRadio's SDR-1000 (bottom), with digital circuitry connected to the antenna. Notice SDR-14 does not use sound card in processing chain.

The SDR-14 is supplied with SpectraVue software by Moetronix, Figure 4. This software includes Raw I&Q, 2D, 3D, Continuum (power vs. time) and waterfall displays. Operation is very basic and does not include a frequency/mode database function. On the plus side, all operations are very intuitive and do not require any manual reading before you can begin SWLing. However, don't expect receiver monitoring features such as memory storage or direct access database. It does not yet exist. I'm sure with the openness of the software we will see many enhanced versions on the Internet.

Figure 2 - FlexRadio SDR 1000 Transceiver with RFSpace SDR-14 and ICOM PCR1000 receivers sitting on top.

The SDR-14 is capable of recording up to 150 kHz of spectrum to a hard drive in real-time at a rate of 52 GB/day. The stored file can later be played back and analyzed, using full frequency tunability in 1 Hz steps and changeable demodulation modes, just as if the 150 kHz worth of signals were being received "live."

The SDR-14 is about the size of the ICOM PCR1000. It comes with a small wall 12 volt power adapter, USB cable, 14 page *User Guide* with Circuit Basics and software on CD-ROM. One thing you may need to buy is an SMA to BNC adapter, since the SDR-14 uses all SMA connectors.

The SDR-14 was operated on a number of Pentium III PCs in the 800 MHz range, with 256 MEG RAM and Windows 95SE and XP. It operated without a problem on all systems. The software loaded quickly and is well behaved.

Comparing the Radios

The first thing that you will notice from Figure 2 is the size difference between the Flex Radio Systems SDR-1000 on the bottom, the RFSpace SDR-14 top right and the ICOM IC-PCR1000 top left. Remember, the SDR-1000 is a fully functional transceiver, with a 1 watt transmitter included. Space for a 100 watt power amplifier is provided for in its box.

Looking at the two block diagrams of the SDR-14 and the SDR-1000's receiver section in Figure 1, similar design philosophies are obvious. Less obvious is the method that two companies have chosen for their data link to the PC. The SDR-1000 uses the PC's parallel or printer port and the PC sound card input. The SDR-14 uses the USB port for digital signal transfer. The USB method is capable of processing up to 150 kHz

Summary of "Live" Monitoring Results

Receiver	SDR-1000*	SDR-14	PCR1000
WWV AM - Strong Sig in Clear	1	1	3
NY Aviation Radio USB Strong Sig - QRM	2	1	3
20 Meter Ham USB strong sig - QRM	1	2	3
40 Meter Ham LSB very very weak sig QRM & QRN	2	1	3
Overall			
Max sensitivity	3	2	1
Usable sensitivity	2	1	3
Selectivity	1	2	3
Sound Quality	2	1	3

*=transceiver

Figure 3 - Table of "Parallel" Monitoring Results - Using MK 1 eardrum and forty years experience

of signal bandwidth.

The SDR-14 comes with a power supply. The SDR-1000 does not.

The SDR-1000 uses BNC connectors; the SDR-14 uses SMA.

Top end of the SDR-1000 is 65 MHz. The top end of the receiver input of the SDR-14 is 30 MHz.

The resolution, or accuracy, of the A/D converter is different between the two SDRs. FlexRadio's SDR-1000 utilizes the sound card which typically has a 16 bit resolution, but can be as high as 24 bit, while RFSpace's SDR-14 uses a 14 bit A/D converter. On paper, the high bits should result in a listening difference. However, sound card qualities vary wildly. As we saw in Part 1 (Nov 2004), some sound cards will not work with the SDR-1000, and some give less than optimum SDR-1000 performance. The SDR-14 removes the sound card issues by performing that processing internally.

❖ Setting Up Listening Tests

Since each radio had a different interface to the PC (USB - SDR-14; Parallel - SDR-1000; and Serial - PCR1000) they were all connected to the same PC simultaneously. Some interference was noted from the SDR-14's USB port. In order to minimize cross interference, only one radio software was operational at a time. The PC used was an 800 MHz Pentium III, with 256 MEG of RAM running Windows XP Professional.

The antenna used was a coax-fed dipole cut to 7 MHz and connected to the radios via a B&W 5-position sealed antenna switch. Propagation conditions during most of the tests were terrible as a result of a severe solar storm.

The A-B-C testing of these radios were done within seconds of each other, using the same antenna and PC and the MK 1 eardrum. Although test equipment was available for exact measurements, even military contractors use on-air listening by experienced operators as the final test. As a shortwave listener with experience using receivers from many manufacturers over the past forty years, I guess I might qualify.

❖ The Test Performed

The receivers were controlled using the manufacturers' "stock" programs; therefore, the ICOM PCR1000 revision 2.2 software was used, not RadioCom. We will reflect on this choice later.

The radios were used in four different and varied monitoring situations:

1. WWV - Strong and in the clear AM signal.
2. NY Aviation Radio - Utility station, nearby stations QRM, USB signal
3. 20 Meters - Strong Ham station with nearby stations QRM, USB signal
4. 40 Meters - Very weak Ham station with noise QRN and nearby stations QRM, LSB Signal

These four presented varied listening environments while providing a challenging testing procedure.

❖ The Test Results

The test results are seen in Figure 3. As was previously stated, these tests were made while a major solar storm was coming off its peak, with reports of communications black-outs in all shortwave bands around the globe. The numbers in Figure 3 give relative ranking of the three receivers – a "1" grade being the top in producing the most intelligible signal.

In a number of situations, two receivers were so close in performance they should have been awarded ties. However, in order to give a level of performance differentiation, we made an admittedly subjective judgment. We made one exception. If you look at the "WWV" row, you will see that both ISRs performed perfectly equal in all respects and were both given a "1". In fact, the PCR1000 only missed a "1" because of its lack of variable filtering, giving the ISRs the ability to see and decode the signal sidebands.

The "Strong Ham USB signal on 20 Meters" was surrounded by lots of weaker, but still copyable ham stations. Here the SDR-1000 gave the cleanest results with the SDR-14 right on its heels. On both, the DSP filters gave a clean, stable result, but the SDR-1000 seemed to have finer filtering capabilities. The PCR1000 had some problems with the adjacent signals and what may have been front-end overloading, but it still gave acceptable results. In many tests, the PCR1000 indicated the most front-end gain. However, in a number of cases it was too much, allowing strong

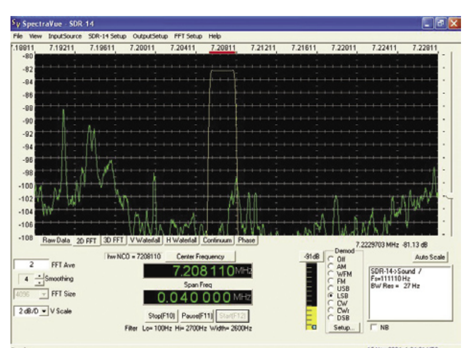

Figure 4- SDR-14's main operational screen showing a very, very weak signal that is still copyable.

WiNRADiO SDR Comment

Dear Editor,

In our view, the November, 2004 article, "Software Definable Radio Now Available to the Public" presented incorrect and misleading information to your readers. The statements "the world's first SDR that anyone off the street can buy," and "right now, you cannot get another SDR on the consumer market at any price," are not factual.

As correctly defined by the author, SDR is essentially a technology where a significant portion of the signal processing functions (especially demodulation) is performed in agile software, as opposed to traditional hard-wired circuitry. He refers readers to a good web site to view the professionally-accepted definitions of SDR: http://www.sdrforum.org/tech_comm/definitions.html

The writer also correctly states that a soundcard and PC-based software can be used to perform a SDR task to advantage. This is exactly what the WiNRADiO G3 series receivers has been doing for a long time – the first of three such products, the G303i, was released approximately two years before this article was printed (see http://www.winradio.com/g3).

The reviewer's impartiality is brought into question when he asks, "Is there a company providing an 'out of the box' software definable radio?", then answers "yes," and selects one recent manufacturer, even though our receiver has been extensively reviewed by MT and other reputable magazines.

The fact that our G303i receiver was the first commercially-available SDR was reported by the highly-respected WRTH (2004 edition), which awarded it a five star rating. Our prices, which have been lower than comparable stand-alone equipment, underscore our claim of the "first commercially available SDR receiver."

WiNRADiO appreciates this opportunity to correct the misstatements in the article. In addition, we invite fair competition, and this comment is in no way directed against the manufacturer being mentioned in the article.

Sincerely,
Milan Hudecek, Managing Director
WiNRADiO Communications

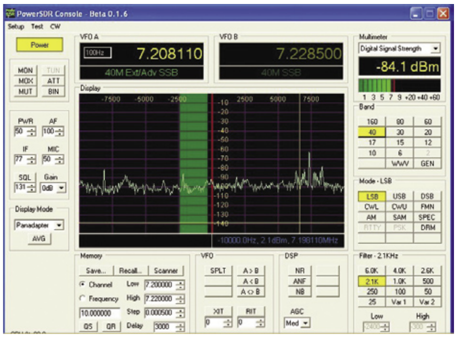

Figure 5 - SDR-1000 pulling the same extremely weak signal from out of the noise.

adjacent signals to enter.

Interestingly enough, the two SDRs switched rankings on the "NY Aviation Radio" medium strength USB signal. Here, there was a strong shortwave broadcast station nearby. All receivers again acquitted themselves with acceptable performance. The PCR1000 had the most problems, again possibly a result of overloading. However, the SDR-14 seemed to give better results on this medium strength signal during conditions of signal fade. This may be indicative of a sensitivity edge over the SDR-1000.

❖ Separating the Crowd

The toughest test was monitoring a very, very weak 40 meter (7 MHz) ham signal in the LSB mode. Weak signals were all around and on top of the target signal. Atmospheric noise was terrible. For all purposes the band should have been considered *dead*. Lots of signal fading was also present. During most of the time the PCR1000 did think the band was dead; words were intelligible about 10% of the time, only on signal peaks.

The surprise came when the antenna was switched to the SDRs. Both gave almost 90% copy, although their displays hardly indicated the presence of a signal (see figures 4 and 5). Notice that both signal meters and displays are indicating -84 and -91 dB, right down in the noise. The SDR-14 again seemed to have the edge. But here the SDR-1000's filtering methodology made up for some of the sensitivity difference for a very close race.

❖ Overall

Here we have to be very careful. The PCR1000 gave the impression of having the hottest front-end sensitivity. However, in some situations it was too hot, dragging in unwanted signals. It should be noted that the SDR-1000 was operated with its front end preamp in its lowest setting – 0dB versus a possible 24 dB gain setting.

For best "usable" sensitivity, both software radios were great. The SDR-14 receiver seemed to edge out the SDR-1000 transceiver. This small difference may be a result of loss in receiver/transmitter switching circuits.

❖ Be Selective

Selectivity was clearly won by the software radios, especially in high noise conditions. All three receivers have at least one form of noise reduction. The SDR-1000 has three. However, these tests were made without noise filtering. The SDR concept, coupled to the continuously variable DSP filters, make for an unbeatable combination. In selectivity, the SDR-1000 edged out the SDR-14, which may be a result of its high bit A/D converter.

Performing the selectivity test made me reconsider the choice of the PCR1000's software. If RadioCom, with its DSP filtering, had been used instead of the ICOM software, the selectivity results might have been closer. However, due to the software radios' open source programming there will no doubt be many third party programs springing up that may improve on their performance as well.

Four Tiers of Software Radios

From the SDR Forum website FAQ

http://www.sdrforum.org/tech_comm/definitions.html

The term "Software Radio" and many variants ... have been proposed to reflect various qualities of radio systems whose functionality is partially implemented in software ... A hierarchy of "Tiers" is proposed to describe various degrees of SDR implementation.

Tier 1. Software Controlled Radio

Radios in this category have control functionality implemented in software, but do not have the ability to change attributes, such as modulation and frequency band without changing hardware. This includes models with a switcher and a group of independent multiprocessors in a common case.

Tier 2. Software Defined Radio

The Tier 2 system provides a broad operational range under software control without hardware change. These systems are typically characterized by a separate antenna system followed by some wideband filtering, amplification, and down-conversion prior to receive analog-to-digital conversion ... This front-end equipment represents a constraint on the frequency coverage of the system and its performance. It may be necessary to switch antennas to obtain the entire frequency range.

Except for these constraints, however, the system is fully capable of covering a substantial frequency range and of executing software to provide a variety of modulation techniques, wide-band or narrow-band operation, communications security functions (such as hopping), and meet the waveform performance requirements of relevant legacy systems.

An SDR is also capable of storing a large number of waveforms or air interfaces, and of adding new ones to that storage through either disk or on-line load ... The system software should also be capable of applying new or replacement modules for added functionality or bug fixes without reloading the entire set of software.

Tier 3. Ideal Software Radio

This system has all of the capabilities of the Tier 2 system, but eliminates analog amplification or heterodyne mixing prior to digital-analog conversion. It provides dramatically improved performance by eliminating analog sources of distortion and noise.

Tier 4. Ultimate Software Radio

This system description is intended for comparison purposes rather than implementation. It is a small lightweight component with very small current drain that can easily be incorporated into personal devices. It requires no external antenna, and no restrictions on operating frequency. It has a single connector that delivers the desired information in the desired format, typically digital. The connector also accepts information, uses it to modulate a signal, and radiates that signal in the desired waveform or air interface.

The ultimate software radio also accepts control information through its connector to operate and reconfigure the operating software ... Further, it has a large amount internal processing capacity, so with appropriate software it can perform a wide range of adaptive services for its user.

❖ Personal Taste

Sound quality – that intangible, personal preference – is hard to define. The SDR-14 seems to provide a more pleasing sound in most monitoring situations. This may be a result of its use of the PC sound card for an audio-only purpose, or it may be my taste.

❖ Conclusions

Don't sell the PCR1000 short. It performed adequately, took almost no computing power and is the least expensive of the lot. The IC-PCR1000 is available from a number of dealers, priced at around $400 plus shipping.

However, Software Definable Radios are here and rapidly developing. As compared to a computer-controlled receiver, they are the clear performance winners and the future of radio.

The SDR-1000 transceiver and the SDR-1000/RO receiver are available from Flex Radio Systems (**http://www.flex-radio.com**) for $875 and $676 respectively, plus shipping. The software is very monitoring friendly since it is designed for the Ham market. See their website for decoding programs which directly interface to it (such as MIXW reviewed in *Computers & Radio* July 2004 column).

The SDR-14 by RFSPACE (**http://www.RFSPACE.com**) costs $999 plus shipping. Its software is more in the style of test equipment with provision for screen capture. Currently no receiver frequency/mode storage database is provided. We will look more closely at the SDR-14's many features and functions in more detail in a future *Computers & Radio* column.

Enjoy being part of the biggest revolution in radio technology in the past 75 years – Software Definable Radios!