Software Defined Radio Working Group

Report to the ARRL Board
Chairman: Bob McGwier, N4HY
July 9, 2007

About a year ago, many promising amateur radio developments began under the general topic heading of software defined radio. In the last six months, most of these promising developments have begun to be delivered to radio amateurs shacks. We are going to see a new transceiver from Flex Radio. HPSDR has begun to deliver software and hardware to its followers through the efforts TAPR with aid from AMSAT. Linrad has begun a serious experiment in delivery of highly capable network based, distributed software defined radio systems. uwSDR has delivered functional software and though its hardware efforts for VHF, UHF, and above are still under development, the early results show great promise. GnuRadio continues to move forward. Ettus Research, Inc. is close to delivering its first articles of the USRP2. A functional OFDM modem has now been implemented in GnuRadio and development on it continues with great promise for future amateur radio use. Radio manufacturers outside of Flex Radio have begun to pay attention to some of its developments and are now shifting their marketing to include claims of being software defined radio and many are now showing live, very sensitive panadapters of the type pioneered by Linrad and Flex Radio in the PowerSDR software.

Flex Radio Flex5000A

Figure 1: Flex 5000A front panel at Dayton 2007

The Flex 5000A is in beta test with hardware and software developers working on the last of the pieces to bring the puzzle together. The radio is very simple looking outside as can be seen in figure 1 but inside, there is very little resemblance to the SDR-1000 and indeed, the number of possible configurations with the hardware is going to be a bit bewildering. The radio will require lots of excellent manual writing. Fortunately, Flex

Radio has Joe DeGroot, AB1DO, a professional technical writer, doing that job and Tim Ellison, W4TME maintain the web site and a really nice knowledge base to aid the users. This radio definitely needs connectivity to the web to use because of the constant stream of upgrades and abilities and documentation that becomes available. It will accept a standard 7 around 1, 8 pin connector with a near equivalence to SOME Yaesu radios. The bright LED shows power on/off conditions.

The main new features in the radio are full duplex operation is available on the base unit. The measured key closure to rise time is under 20ms on CW. PowerSDR has been modified to operate in this full duplex manner and will support rapid changeover requirements for many modes. The hardware switches faster than the software can CURRENTLY support. The claimed dynamic range, IP3, spurious emissions, sensitivity, and more are much improved. The image balancing algorithm is now operative on both transmit and receive and will done by a newly written algorithm. Hints of the method have been given by VE3NEA and will be described briefly under Rocky SDR below. An article on the algorithm for QEX is in preparation. An impulse generator is in the radio to allow for training of the Linrad style noise blanker. Carrier suppression is done in hardware and by band. It connects to the computer with a single wire, firewire, and needs no internal sound card. The audio interface inside is based on the Akashi AKM5394A. The SDR group chairman owns a Lynx L22 and an Emu Creative soundcard. Both have flat response with very low noise and intermodulation distortion over a full 192000 Hz with that sample rate and excellent channel separation and both use the Akashi part. As a result, this was chosen for the Flex 5000 and the HPSDR Janus card for all of the right reasons. The Janus will be reviewed later. One of the most impressive features of the Flex5000 is revealed by looking at its back panel, seen in figure 2.

Figure 2: Flex 5000A back panel at Dayton 2007

The RF input output system on the Flex 5000A is impressive. It has 3 antenna jacks (SO-239), xvtr-tx/common and xvtr-rx which will support both transverters with common IF or duplex connections. The receive can be operated from separate antennas through the use of RX1 or XVTR-RX ports. The RX path can be broken with an internal switch to allow preamps and other devices to be switched into line with RX In and RX Output provided. An output is provided for power speakers, balanced microphones with balanced input for RF suppression, balanced out, line out, ground terminal, firewire IN AND OUT for daisy chain of devices, and more. The standard ¼" stereo plug is provided for keyer paddle input. A complete duplicate receiver will be available as a plug in module and provided with is own external connector on the back plate (RX2). It is clear that this radio provides a dizzying array of capabilities. It will probably be some time before all of the support for its capabilities is fully in place. But this has become standard practice for Flex and its customers. New software with new capabilities is regularly made available to its customers through web site download and with subversion download for the "latest and greatest" beta software. The radio should start shipping this summer according to recent Flex announcements on their web site.

HPSDR

As told in previous reports, HPSDR has grown "organically" originally from Flex SDR1000 owners looking for more experimentally friendly hardware and an outlet for their ideas. It has now grown well beyond that group though it is clear they are the core around which it is built. It has now grown to a very large number of offerings, most quite impressive, and with kitting and financial support from TAPR and AMSAT, the first products are coming out and more are soon to follow. The earliest successes are the release of the Atlas and Ozymandias boards. We have previously described the Atlas board as the back plane for the experimental boards from HPSDR and will proceed to the Ozymandias board as shown in Figure 3. This board is the "brains" of the HPSDR system. It provides interconnection with the PC using USB2. It has a DB25 and DB9 plug on it and these are reprogrammable in software. It uses a standard USB interface and borrows heavily from GnuRadio and USRP for its code to run the USB2 interface. It has an upgraded processor from the USRP in that it uses a Cyclone 2 from Altera. This board will be able to run some significant DSP algorithms in the Cyclone while it is playing traffic cop for the data along the Atlas bus. It is currently operating the Janus board seen in Figure 4. The Janus board, designed and coded by Phil Harman, VK6APH and Bill Tracey, KD5TFD, is a sound card replacement and provides a standardize and optimized interface for many software defined radios. It uses the Akashi AKM5394A for an outstanding dynamic range and noise floor on receive. It provide microphone digitization using a codec as well as CW sidetone. It has a pulse width modulator for the transmit signals which is implemented in a CPLD (tiny FPGA). This board will provide a lower noise floor, and greater dynamic range with the SDR1000 for example because that radio is noise limited at the back end of the mixer. This board should also allow Flex owners to modify their radios to remove the noisy instrumentation amplifiers and take the quadature sampling detector signals directly, improving the overall performance of the system substantially.

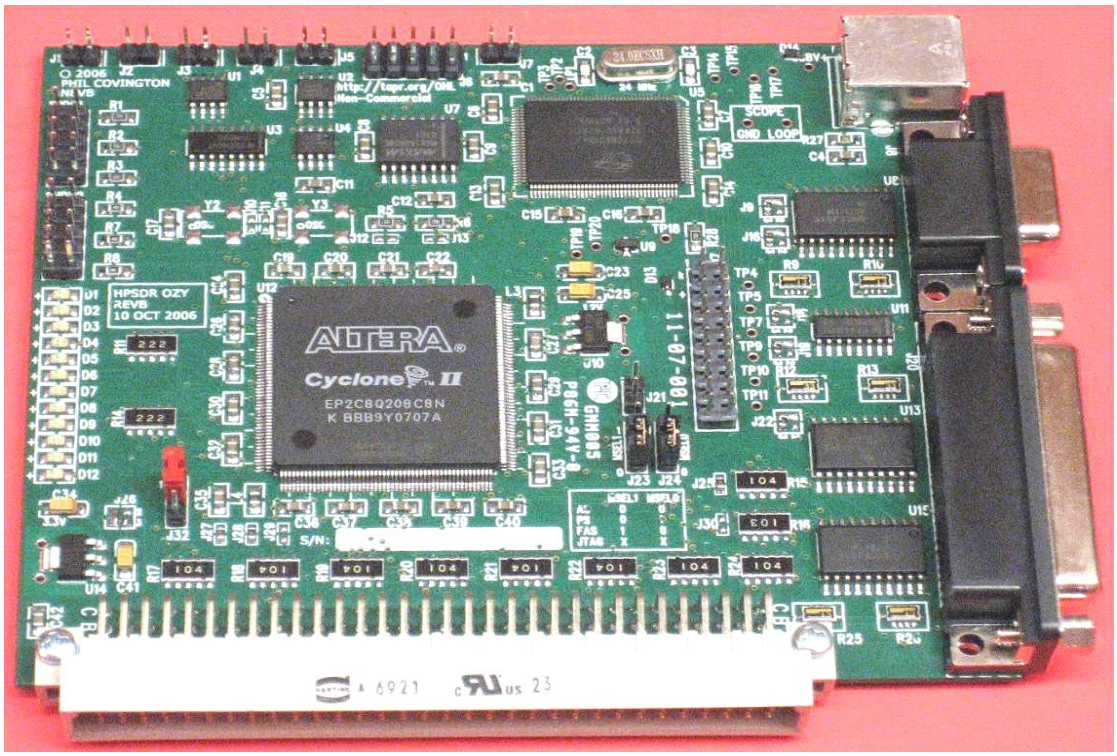

Figure 3: Ozymandias or Ozy by HPSDR

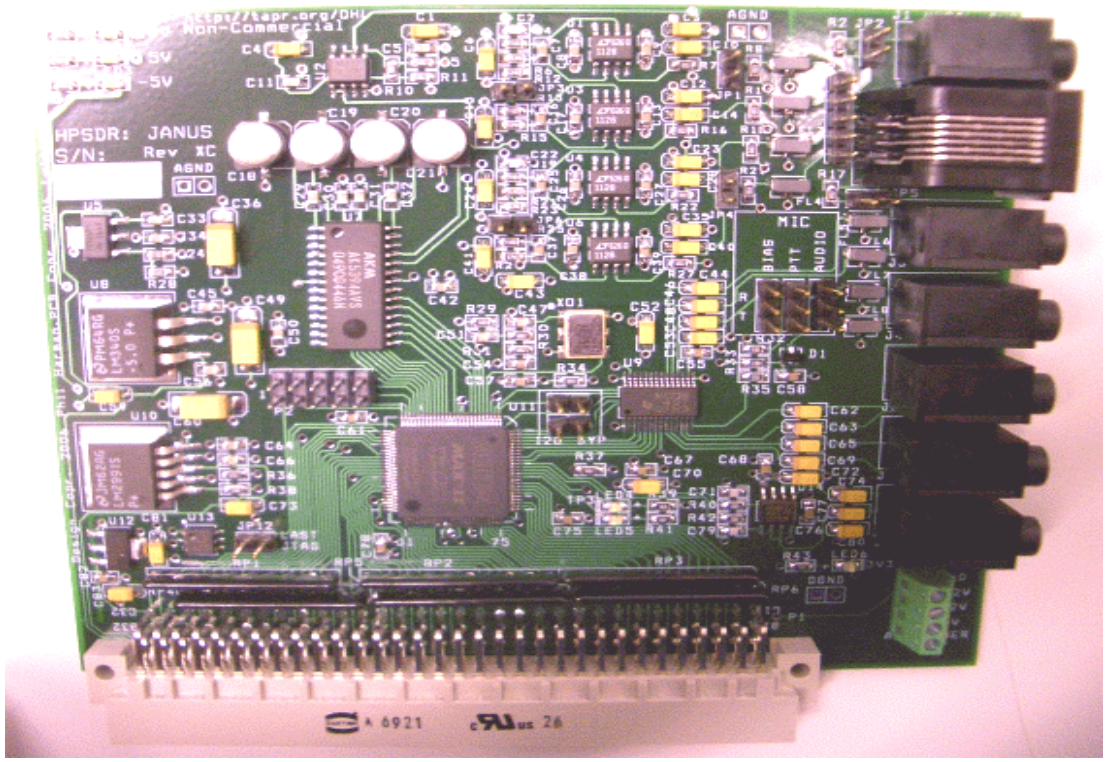

Figure 4: Janus board by HPSDR

In addition to these offerings, other substantial developments are taking place. A low power software defined radio is being implemented with the help of Microchip using the dsPIC33 as its software defined radio engine. It will be used in Suitsat-2, a follow up to the very successful Suitsat which was thrown (launched?) from the international space station. This time it will provide a full transponder (70 cm up and 2m down) as well as experimental beacons, CCD camera images transmitted using SSTV and more. The HPSDR project is known as Odyssey because of the unique journey it is intended to take. But the board itself is capable of much more. We expect this development to lead to releasable product by years end. The Suitsat-2 launch is to in honor of the 50-th anniversary of Sputnik and a birthdat of a the famous Russian scientist Tsiolkovsky. Lou McFadid, W5DID is project manager for Suitsat-2. SDR Working group members N4HY and AB2KT are writing the software for the radio part of the Oddysey which is called Siren. (You need to read up on your mythology to understand the relevance of these HPSDR names).

Also to be released is a very high performance receiver board based on a very high speed and high dynamic range A/D. This board is called Mercury because of its high speed A/D. It will be able to digitize all of the HF spectrum! Its FPGA will be able to filter and downsample to entire amateur radio bands or to narrow band channels. The initial numbers from its primary developer, Phil Harman VK6APH, show that it should be one of the best receivers ever measured in the ARRL labs. The capabilities provided by the wide band front end will enable some fantastic SDR work to be done. Again, we are expecting this to be released from TAPR by year's end. Phil is also doing the Penelope board, which is a transmit board, also based on a high speed part, but this time an A/D. It is the matching "transmitter" for the Mercury. Both will plug into the Atlas back plane. We are expecting much more to follow this year.

Linrad

Leif Åsbrink, SM5BSZ continues to impress us with his many contributions to the state of the art in software defined radio with the suite he calls Linrad. Leif has built a Linrad network capability which now includes the ability to support multiple operators using a single piece of hardware intended for VHF+ work (his WSE very high performance hardware). Linrad has added automated polarization diversity reception. This means that operators do not need to choose, vertical, horizontal, right hand circular, etc. They may take a vertically polarized antenna and a horizontally polarized and the software will find the optimal combining of these two. This is, to my knowledge, the first real smart antenna work done in amateur radio, where the dsp decides how to combine the signals.

Leif continues to enhance the software and it is now widely used in Windows and Linux. He has added a component he calls Watzo, which is a waterfall zoom operation which can be supported across a network to allow multiple computers to share the burden of the dsp computations. We expect much from our fellow SDR group member and he does deliver. The Linrad software has been used in a GUI based package by I2PHD, Alberto Di Bene for Windows which he calls Winrad. Leif continues to be the source of much

inspiration for other sdr developers. DttSP by Brickle and McGwier, will contain the smart noise blanker and probably the polarization diversity will be used for plain diversity with the dual channel full duplex Flex 5000. That Leif has done a network capable sdr system has inspired others to make a real attempt to do it as well. Leif is a major contributor to the state of the art.

uwSDR

uwSDR is a development led by Chris Bartram (of mutek front end fame) with a lot of technical work being done by Jonathan Naylor, Grant Hodges, and several others. The goal is to provide inexpensive and easy to use microwave hardware and a GUI that is friendly for VHF+ operation. Jonathan Naylor is the author of the uwSDR GUI and the sdr is based on the DttSP SDR core by Frank Brickle and Bob McGwier. Figure 5 shows the GUI. Currently planned for the uwSDR offerings are 2.3 GHz, 1.2 GHz, and .435 GHz modules.

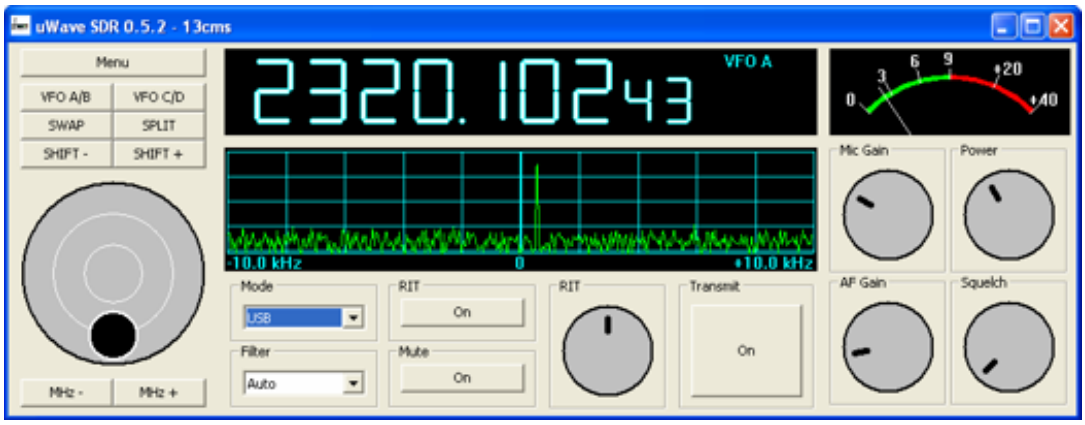

Figure 5: uwSDR GUI by Jonathan Naylor

GnuRadio/USRP2

GnuRadio continues to be a hot bed of development in software defined radio. Matt Ettus, Bob McGwier, and Tom Rondeau have written an OFDM module for the software suite. This OFDM module will be part of a building block that will enable wide spread experimentation with this digital mode of operation and various forms of forward error correction and automatic request for resend. Matt Ettus is about to release the USRP2 as shown in Figure 6. Also, GnuRadio will be ported in the next several weeks to the Sony PlayStation 3. The PS3 has a Cell processor in it. This is a DSP supercomputer as well as a bluray player and game machine. It will almost surely allow full motion HDTV to be displayed with Linux MythTV. This is a very impressive speed up in our current operations which are bandwidth limited because of the computer. The USRP2 will also support wider bandwidth operation by changing the method of interface to the computer from USB2 to Gigabit Ethernet. The PS3 should allow for live synthetic aperture radar, bistatic radar with wideband signals, and much more. Tens of Megabits per second data transmission will be usable with the PS3 for example.

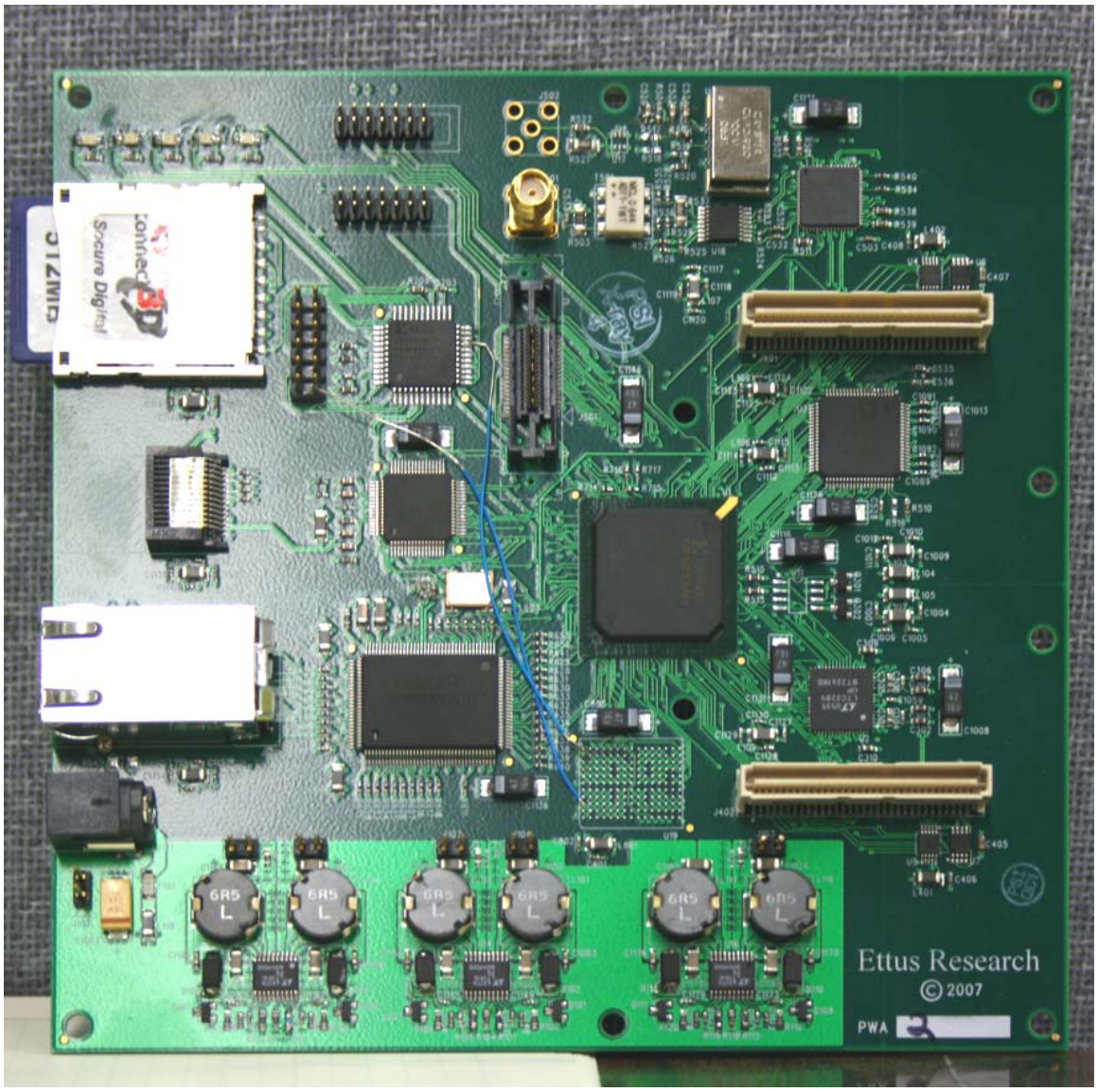

Figure 6: Universal Software Radio Peripheral 2 (USRP2)

GnuRadio has seen many new developers add new features. The system has a full pager demodulation and decoding suite. It has a nearly complete suite of forward error correction modules done by one of its contributors. In addition, it is being modified to allow inband signaling which will allow the critical received signal strength information to be used to modify the settings which will allow the capacity of OFDM and other signals to be maintained at a high level. Also a version of the software element assembly apparatus is being built that will NOT require python to assemble the signal processing elements. This impressive and complex software suite continues to develop at a rapid pace and we can expect a lot of exciting things to be added in the next few months. The demand for this suite of software by commercial and government agencies have caused a course for professionals to be put together by Jonathan Corrigan, AE6HO. SDR working group members Eric Blossom, K7GNU and Matt Ettus, N2MJI continue to lead this group of diverse developers.

Rocky/VE3NEA

Alex Shovkoplyas, VE3NEA may be more familiar to many as the author of DxAtlas. Alex is a true polymath with many interests. The softrock radio series inspired Alex to do more with his abilities in the area of software defined radio. Alex wrote and released the Rocky SDR system available at http://www.dxatlas.com/rocky and is a free offering. Alex's software has contributed several very good ideas to the software defined radio community including the idea that we can do automatic IQ imbalance correction, some very interesting nonlinear operations on power spectra to allow us to better see the signals we wish to see in panadapters and waterfall displays. The rocky interface show in Figure 7 hides the complexity of the software in a very simple user interface. Alex makes all of the choices normally available to the user computed through his definition of optimality. He maintains optimal dynamic range in his automatic gain control system as well as other features. His system does a very good job of shaping the CW signals. Indeed, Alex wrote a recent QEX article on the subject of optimal CW shaping. Alex's most recent contributions include a tool to do audio processing on microphone signals bound for software defined radios. Alex has become a very important contributor to the amateur radio SDR community.

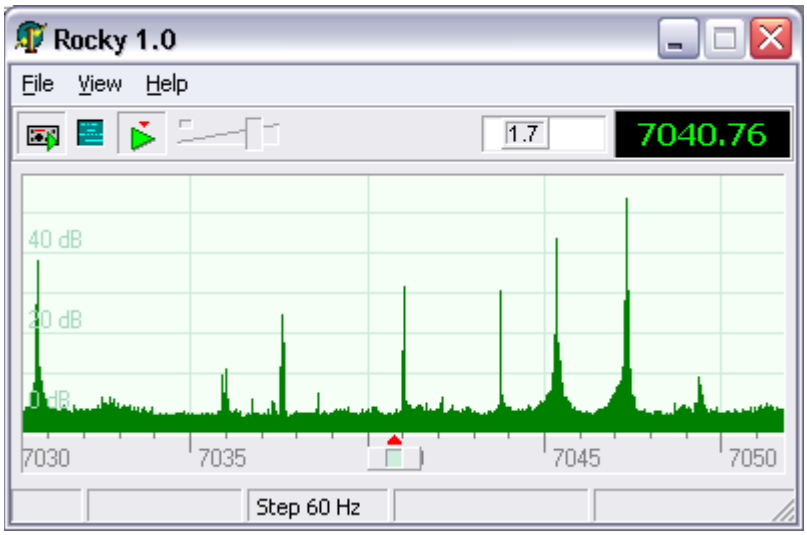

Figure 7: The Rocky SDR GUI

RF Space SDR-IQ

Peter Ibelings, N4IP and Moe Wheatley, AE4JY have long been known for their work in software defined radio hardware and software. Moe is well known for his pskcore.dll which is the basis for so many psk31 software suites. Peter designed and released the SDR-14, another SDR by RF space a few years ago. They have upgraded that offering considerably to give us a software defined receiver in a beautiful box which is powered by the USB2.0 cable that is its single connection to the PC.

Shown in Figure 8, the SDR-IQ promises to be a real favorite amongst experimenters and operators alike. The receiver is run by Linrad (as is the SDR-14) as well as software

Figure 8: SDR-IQ USB 2.0 powered SDR receiver

written by Moe Wheatley's Spectravue software. Moe's software suite is very impressive and makes a very interesting tool for use with many software defined radios.

SoftRock Series

What can one say about Tony, KB9YIG, the father of the softrock SDR radios? Tony, who almost gives away the radios (and indeed will build them for the inept) has done as much as anyone to promote the use of software defined radio processing systems. Tony is in the thousands of radios sold. It has to be approaching 10,000 radios, all sold for well under $100, many for under $50. He operates a group on yahoo which may be visited here: http://groups.yahoo.com/softrock40. Tony has recently released a transceiver in this series, the softrock RXTX which may operate on 160, 80, or 40/30 meters. It has a fixed IF in these bands and then tunes +/- the IF bandwidth determined by the underling sdr software. If your audio system supports 192000, it will cover almost 200 kHz of the band in question. These kits sell for $31 per band. It is remarkable to say the least. Rocky SDR and PowerSDR both will work with the Softrock RXTX Tony is a international asset. See Tony in Figure 9 at Dayton where he brought hundreds of the radios and left empty handed.

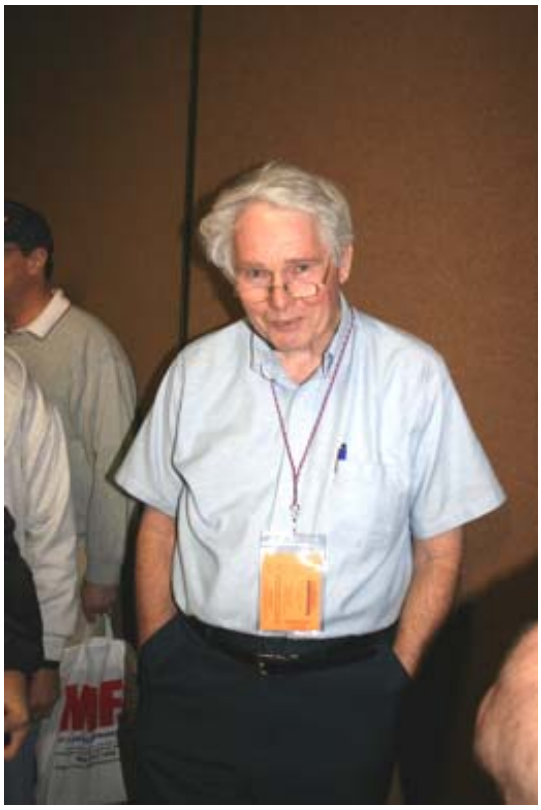

Figure 9: Tony Park, KB9YIG, father of the softrock radios at Dayton 2007

Also at Dayton in addition to seeing the unveiling of the Flex5000, we had a full room attendance at the official ARRL SDR forum where HPSDR was talked about as well as Rocky. Eric Ellison AA4SW led the forum at the request of the chairman. Figure 10 is a picture of HPSDR contributors VK6APH and AA4SW. Phil is a leader in HPSDR as shown above and Eric, in addition to having set up TeamSpeak for almost all of serious amateur radio development groups is now a TAPR director.

Figure 10: Phil Harman, VK6APH , Eric Ellison, AA4SW at TAPR/AMSAT dinner, Dayton 2007

In addition to Phil's major work for HPSDR and his work in support of Flex Radio during the SDR1000 era, Phil and Steve Ireland, VK6VZ are writing a series of excellent articles in RADCOM, the RSGB's publication on SDR. It is extremely well received and provides excellent tutorial material for those who are not trained dsp engineers.

It should be apparent from the brevity of some of these sections that the chairman's job of keeping up with development and presenting it in a small capsule format is becoming more difficult. SDR and soon, cognitively defined radio, smart antennas, and more will grow the size of these offerings. There is amazing development going on now with better hardware becoming available for the RF front ends to radios and with much faster computing equipment becoming inexpensive enough for all to afford. SDR is really mainstream now. It should continue to be highlighted for the directors as it is here that lots of amateur radio's most exciting action is occurring.

Respectfully submitted to the ARRL board of directors,
Bob McGwier N4HY
SDR Working Group Chairman