Software Defined Radio Working Group report to the ARRL
June 20, 2006

It would be hard to overstate the impact that software defined radio is beginning to have on amateur radio technical development. This report cannot begin to do justice to the subject because it would take much more space and time than we have available to devote to such a report. We will at best give the highlights and we apologize to the board and to those projects discussed here for the abridged version of their wonderful work.

AMSAT SDX

AMSAT-NA and AMSAT-DL have both chosen to adopt software defined radio as a transponder foundation for their future satellites Eagle and Phase 3 Express respectively. The Software Defined Transponders (SDX) will have the ability to completely change modes and to run split modes in the transponder. It may be configured with multiple channels of FM along with a linear transponder.   It will have the ability to automatically control the level of the outgoing signal *by user*. This will prevent large power users (alligators) from dominating the transponder and forcing small signal users into the noise floor since the "agc" is determined *per active signal*.

Figure 1: The DSP heart of the SDX, Dayton 2006

The SDX will be based upon a TI digital signal processing chip.   It will include the ability to use envelope elimination and restoration in the transmitters. This will provide for extremely high efficiency on the downlink transmitters. All of the necessary computations to make this happen will be done in the software defined elements using the DSP chip assisted by an FPGA. The predicted dynamic range at this time is 60 dB more than has ever been achieved by one of major satellite transponders in the design proposed for Eagle. The current software was written by G6LVB who formulated the "by user" agc which he calls STELLA. Frank Brickle, SDR WG member and coauthor of DttSP (see below) is porting DttSP to the platform for the AMSAT SDX and the HPSDR SASQUATCH project (see below). Hardware design is lead by Lyle, KK7P.

Figure 2: N4HY and K3IO show the SDX development board in a "module," Dayton 2006

With the help of Microchip, AMSAT is building the hardware for SUITSAT II and it will have an SDX in it. It is based on the QSD technology from the SDR-1000 and uses a Microchip dsPIC33 (PIC with DSP features). Frank Brickle AB2KT and the chair are writing the transponder and beacon code for the dsPIC33.

DttSP

The software defined radio core used in the Flex Radio PowerSDR code has moved on to version 2.0 with many new features and capabilities. It will also be the narrowband processing engine for the HPSDR project described below. A joint effort between Frank Brickle, AB2KT and the chairman, this software will be usable for the AMSAT SDX, HPSDR SASQUATCH (see below), uwSDR (see below) and any other software defined radio projects needing a core of routines to accomplish the basics of being a transceiver. DttSP 2.0 will be the core of many efforts described herein.

Flex Radio becomes mainstream

During the first six months of 2006, Flex Radio went well beyond the one thousandth radio sold. It has entered the mainstream of amateur radio thinking and has a quickly growing worldwide following. Major impediments to its widespread acceptance, INCLUSIVE OF ITS CW KEYING PERFORMANCE, have been completely resolved in the last six months. To quote Lee, W9OY, in a recent note to the flex radio reflector:

> "I worked 6 new ones this afternoon/evening on 30M CW using the
> new code. The ping pong between me and the DX op was flawless.
> I listened using another RX and there is no leading edge
> distortion on the first character even at 60wpm, or even if I set
> the delay to minimum. I used the built in side tone for the first
> time. Thanks to all who brought this to fruition.
> 73, W9OY"

In the chair's opinion, this was the last major hurdle to be overcome by the Flex Radio software developers in laying the firm foundation to proceed to future development.

At Dayton,   Gerald announced that Flex Radio was designing a new product. The new product will be a rack mount communications system that will allow multiple configurations.   In a box a few inches high by "rack" wide,   one may put eight receivers, or two transmitters and two receivers in the chassis. All of the elements will operate as "separates", so they are inherently full duplex.

Figure 3: Flex Radio Prototype   Figure 4: Flex Radio (new radio) Rack mount
Receiver, Dayton 2006   crate, Dayton 2006

Very good performance numbers were shown for the prototype receiver shown in Figure 3. The numbers quoted would make the new receiver the best receive system on the market.   Gerald says that he believes the communications system will be available at Dayton 2007 if everything goes according to plan. Gerald is also planning a very high efficiency transmitter aimed at getting DC to RF efficiencies well over 80% and at the same time delivering stellar IMD and total composite noise.

GnuRadio

Matt Ettus, N2MJI, developer of the hardware most widely used for GnuRadio, made use of some new interesting technology from Analog Devices.   The IQ modulators and demodulators make for a very simple transmitter and receiver mixers and give usable performance in terms of LO and image suppression without the use of an IF filter. Ettus Research has offered boards that cover the entire 70 cm band, 902 MHz band (the entire band), all amateur allocations in the 23 cm bands, and all of the 13 cm bands. The 2400 MHz model, formerly known as Flex2400 is shown in Figure 5. We will be able to do many very interesting experiments with this unit and these units are to be used in building a system for HSMM use.
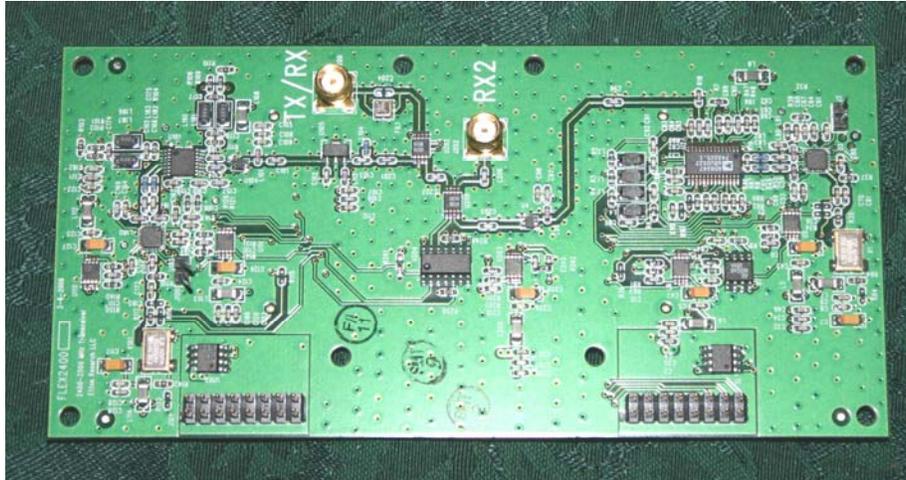
Figure 5: Ettus Research full duplex 13cm transceiver

Two of these new modules may be placed on the Ettus Research USRP as shown in Figure 6. AMSAT is using this board to build cross band transponder demonstration experiments and experimenting with the USRP to provide for electrically steered arrays for its future spacecraft.

SDR working group members Eric Blossom (K7GNU), Matt Ettus (N2MJI), and the chair (N4HY) worked on a packet radio system for GnuRadio using these modules.   We have easily achieved over 1 mbps transmissions, with all modulation, demodulation, packet processing all being done in the host computer. Up to 2 mbps is possible given a fast computer. The 1 mbps was done on laptops and not high end laptops, but Celeron based Linux laptops.

OFDM work has been underway for a year and it is expected than an OFDM package suitable for use on VHF and microwave will be available from GnuRadio in the next few months.

GnuRadio has been successfully ported to Windows and Mac OSX. This should allow for a larger audience to use the SDR hardware and software.

At Dayton, the ARRL HSMM working chair and the SDR WG chair agreed to cooperate to write articles for QEX and QST about the use of GnuRadio for HSMM and other digital transmission systems. This will provide for a very credible and much less expensive alternative than some of the current commercial offerings. In addition, it will be much more versatile because of the open source and open specification nature of this project. There is already a digital vocoder in the GnuRadio software suite and others can easily be added.

Phased array, MIMO, smart antenna, and many other exciting applications for this SDR are being worked on as this report is being written. GnuRadio and Ettus Research are being used in several communications projects for the U.S. government amongst many others and the U.S government has and will participate as an open source contributor.
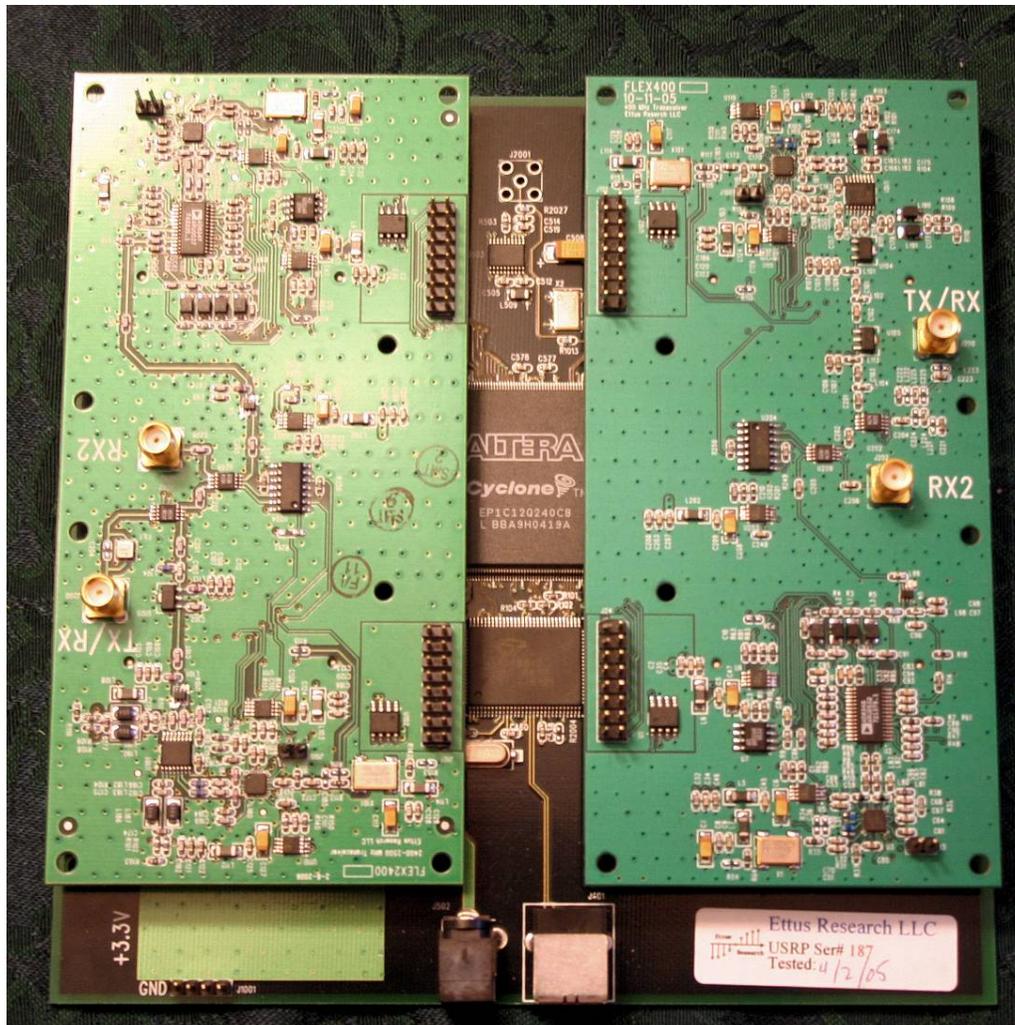
Figure 6: 70cm and 13 cm transceiver modules on the USRP

HPSDR

A spin off of people who are users, owners of the SDR-1000, and contributors to the Flex Radio's open projects happened in the last few months. It has attracted many people not associated with Flex or the SDR-1000. *High Performance Software Define Radio,* hereinafter HPSDR is exploding in potential and development.   It is dedicated to open software and hardware development for the good of the community.   The first major pieces of the hardware are now available in kit form from TAPR.   TAPR and AMSAT, in a move reminiscent to their joint sponsorship of the "DSP project" in the mid to late 1980's have decided to support or cosponsor the project. AMSAT hopes to gain valuable technology for its SDX and digital transponder experiments. A leader in the HPSDR, Phil Covington, N8VB is the designer of the "back bone" of the project. It is the foundation will hold up the rest of the contributions in platform that will allow for power and signals to be passed between modules. It is appropriately named Atlas. It is currently available in kit form from TAPR.   Soon to be available from HPSDR is the JANUS project. Janus was the Roman God of gates and doors. This module is to be our A/D, D/A gateway for narrowband (up to 200 kHz) I/Q processing. The JANUS project
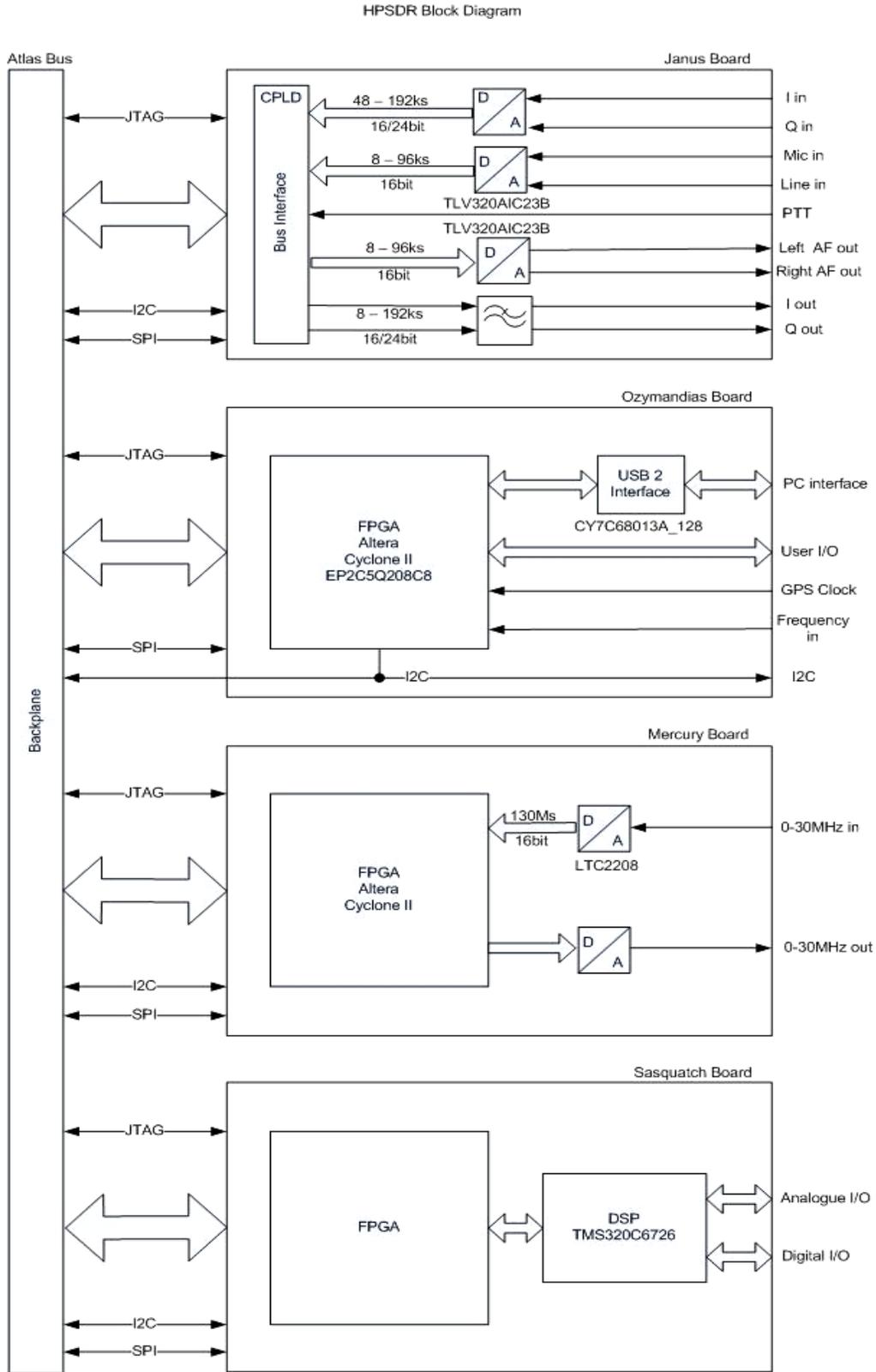
HPSDR Block Diagram

Figure 7: HPSDR Block Diagram

is the HPSDR's effort to escape the prison of using sound cards for the last IF in our high performance narrow band SDR radios. We are at the mercy of the sound card manufacturer to provide good drivers, consistent analog interfaces.   Led by Phil Harman VK6APH and Bill Tracey, KD5TFD, it is a fully functional sound interface for any purpose but is designed to work successfully with the SDR-1000 and PowerSDR. It will definitely not be limited to that platform. It will generate signals using an FPGA and pulse width modulation (PWM) and will provide for full QSK CW for all future projects. It is based on an Akashi Codec that is heretofore only been available on extremely high end sound cards. It is currently available in kit form from TAPR.   Soon to be available from HPSDR is the JANUS project. Janus was the Roman God of gates and doors. This module is to be our A/D, D/A gateway for narrowband (up to 200 kHz) I/Q processing. The JANUS project is the HPSDR's effort to escape the prison of using sound cards for the last IF in our high performance narrow band SDR radios. We are at the mercy of the sound card manufacturer to provide good drivers, consistent analog interfaces.   Led by Phil Harman VK6APH and Bill Tracey, KD5TFD, it is a fully functional sound interface for any purpose but is designed to work successfully with the SDR-1000 and PowerSDR. It will definitely not be limited to that platform. It will generate signals using an FPGA and pulse width modulation (PWM) and will provide for full QSK CW for all future projects. It is based on an Akashi Codec that is heretofore only been available on extremely high end sound cards.
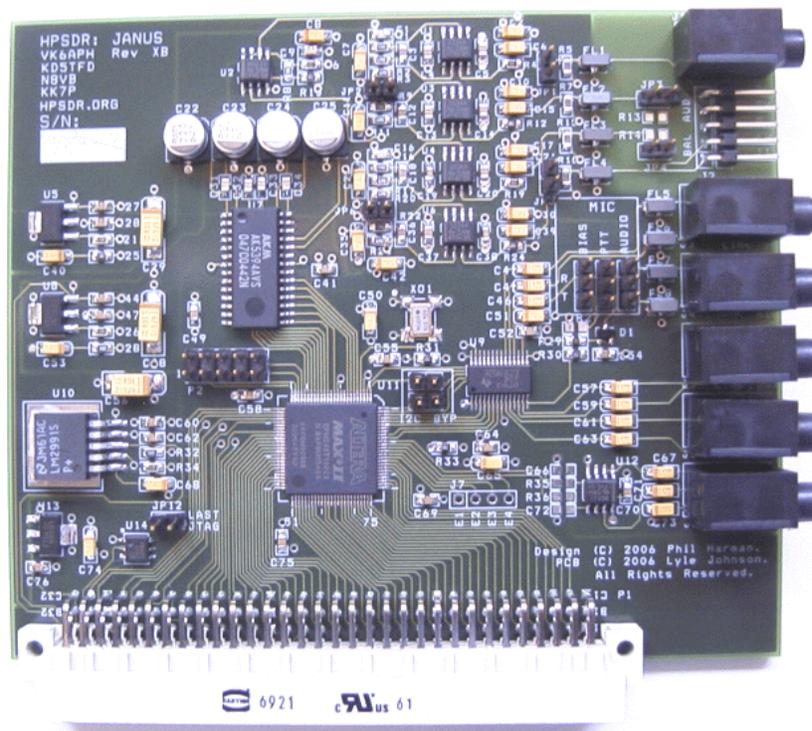

Figure 8: HPSDR's JANUS A/D, D/A module

Other planned plug in modules from HPSDR include OZY (for Ozymandias), Mercury, Sasquatch, Gibraltar, Horton, and Pinnochio.   Ozymandias has Covington, N8VB as the lead designer. It is the heart of the HPSDR system as it will provide control over the backplane and a USB port to the PC.   Mercury is essentially a high speed A/D, D/A, and digital downconverter board. It is "half a USRP" with a much improved A/D and D/A. The DDC will be done in Altera Cyclone II FPGA. A DDC consists of filters and a numerically controlled oscillator.   Sasquatch is a DSP board with a FPGA on it for coprocessing.   Sasquatch is also at the heart of the proposed SDX for AMSAT. It is planned to have a TI TMS320C6726 on it and the DttSP SDR core will run on it. Sasquatch lives in Washington with its designer, Lyle Johnson, KK7P.   Horton (as in Horton hears a who) is a narrowband receiver system/mixer based on the QSD (quadrature sampling detector) used in the SDR-1000. Horton development is being lead by the chairman N4HY with VK6APH, and N8VB. Pinocchio is a bus extender card and now the name becomes more obvious.

HPSDR, with its extremely lofty ideals, and fantastic array of talent both software and hardware, promises to have a major impact on amateur radio on analog, digital communications and on frequencies from DC to 47 GHz.

Linrad, Wlinrad, and Xlinrad

Linrad has undergone a major rework over the last year.   Leif has restructured the SDR suite to be multithreaded and has also released version that support X11 windows for Linux and through MinGW, he now supports Microsoft Windows machines as well. It has become very stable and still has a large collection of signal processing routines that should be exploited for many purposes. Alberto, I2PHD has almost released a windows version he calls WINRAD. Leif continues to make major strides and Linrad continues to be fertile ground for new ideas.

SoftRock

Tony Parks, KB8YIG and Bill Tracey, KD5TFD decided to design an inexpensive easy to use version of the QSD to show off the SDR technology and software to a wider audience. Going through several various designs and iterations, the Softrock was a revolution in terms of exposing others to the software defined radio. DttSP and PowerSDR and later following by many other offerings were applied to the softrock 40. At less than $30 for most versions and at most $50 for the most expensive version, Tony and Bill did a wonderful thing for our community. THOUSANDS of these receiver kits have been sold. Many tried SDR technology because of this offering. Our community and hobby owe these two fine hams a large thank you.
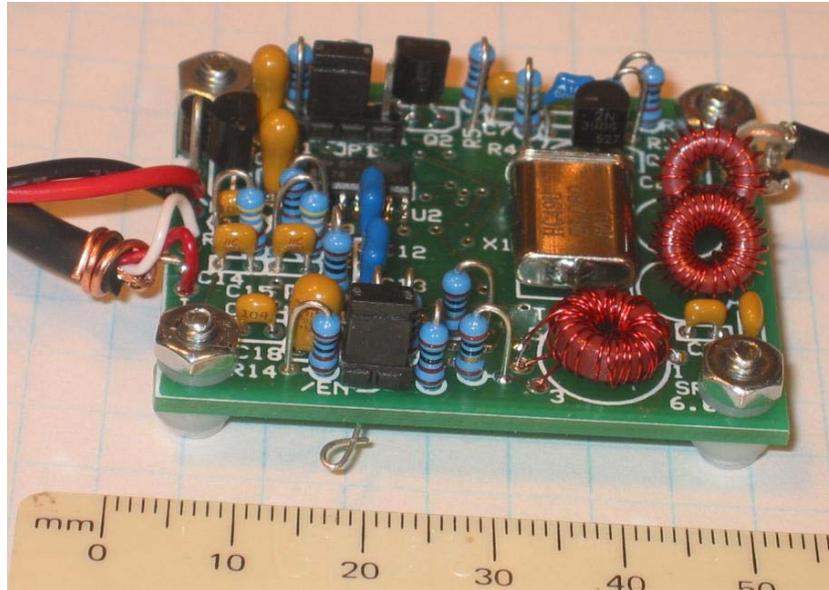
Figure 9: Softrock Receiver a $30 revolution

uwSDR

A very well known radio amateur, Chris Bartram, GW4DGU, former partner and engineer of Mutek, along with several other European amateurs of note, decided to put together some hardware to use the DttSP core and build their own GUI interfaces to support simple, easy to build Microwave SDR equipment. The group, like HPSDR, is only a few months old but has attracted some really terrific talent in Europe and the chair N4HY recently joined this group. Chris has years of experience in producing the well known front ends many of us used as replacements in our transceivers and is also a well known LO designer. This group, like HPSDR, must be watched closely for very interesting developments in the next few months.

It is so exciting to be a member of this working group now and especially to be its chair. This is one of the most exciting areas of amateur radio development. It has returned homebrew, both hardware and software, and kit building in the THOUSANDS of units back to amateur radio. It is an honor to represent the ARRL as its SDR WG chair.

Respectfully submitted,

Bob McGwier, N4HY
Chairman, SDR Working Group