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Report of the ARRL Software Defined Radio Working Group

In May of this year, Doug Smith resigned as chairman of the SDR WG and Howard Huntington (TTF chair) and Paul Rinaldo (ARRL CTO) asked Bob McGwier, N4HY to take over as chair. We added three new members to the working group. They are Frank Brickle, AB2KT, Matt Ettus N2MJI, and John Stephensen, KD6OZH.

This was a bellwether year for software defined radio both in and out of the Amateur Radio Service. Federal Communications Commission, Commissioner Jonathan Adelstein, in remarks to the Global Regulatory Summit on SDR and Cognitive Radio at the SDR Forum in Washington D.C., gave clear indication that the F.C.C would act on Notice of Proposed Rule Making, ET Docket 03-108 which seeks to regulate SDR and Cognitively Defined Radio (CDR). The tone of his remarks show that the F.C.C. is leaning towards encouraging innovation with the minimal regulation required protecting many radio services. An important first for S.D.R. came this year when the F.C.C certified and type accepted Vanu's S.D.R. core for use in cellular telephones. Shortly thereafter, in a clear indication of the power of SDR, this same core was programmed to do iDen, a trunk mobile radio specification. This will enable those cellular telephones using the Vanu core to do "Push to Talk" without a hardware refit. The F.C.C. also noted, in Adelstein's remarks, the clear path forward by combining artificial intelligence style algorithms with software-defined radio to enable dynamic spectrum management with cognitively defined radio (CDR).

Flex-Radio

Amateur Radio has not been asleep during this revolutionary time. SDR WG members have made significant contributions in this area to amateur radio projects. Recently, in ARRL Letter, Vol. 24, No. 26, Flex Radio is mentioned as the contributor of the first truly software defined HF transceiver and Cognitive Radio is prominently mentioned. SDR WG members Gerald Youngblood K5SDR(formerly AC5OG) , Frank Brickle AB2KT, and Bob McGwier N4HY, SDR WG chair, have been working on the Flex Radio hardware and software. This year saw real improvements in both. Flex modified the front-end only slightly, by changing one active device and a few capacitors and resistors and made the SDR-1000 receiver one of the best in the world. Flex has measured the front-end performance at >30 dBm IP3 without the preamp and >20 dBm IP3 with the preamp. They also measured the best 2 Khz dynamic range of ANY receiver in comparison with the receivers listed on the well-known Sherwood Engineering web page comparisons. The software underwent a complete rewrite, which will enable spectacular new features while enabling older "sound card programs" and logging programs to operate with the radio software seamlessly and without extra wires using all virtual control and audio interfaces. The ARRL lab is now reviewing the new SDR-1000 assembled, tested, and calibrated system.

Gnu Radio

Amateur radio operators who are contributors to the software and hardware heavily influence GnuRadio, which is not strictly an amateur radio project. From the Gnu Radio web site:

"GNU Radio is a collection of software that when combined with minimal hardware, allows the construction of radios where the actual waveforms transmitted and received are defined by software. What this means is that it turns the digital modulation schemes used in today's high performance wireless devices into software problems."

This project is led by SDR WG members, Eric Blossom K7GNU, and Matt Ettus N2MJI. This project also saw tremendous progress during the previous year. Version 2.0 of GnuRadio was released and is currently being worked on by K7GNU*, N2MJI*, KD7LMO, AB2KT*, K8UR (TAPR president John Ackerman), and N4HY* (* = SDR WG members) just to name a few amateurs. Matt Ettus released new add-on hardware for the project's Universal Software Radio Peripheral (hereafter USRP) which is also distributed by Matt. These add-ons include basic RX and TX interfaces, which several members have used to directly digitize the antenna voltages on both receive and transmit! With some bandpass filtering, the USRP makes a respectable shortwave receiver, certainly much better than almost all SW receivers sold at electronics stores. The other hardware recently released is a "Cable TV Tuner" which is a wideband receiver for 50 – 870 Mhz called the TVRX. There is now a dedicated software module for a Stereo FM for this unit. The TVRX is capable of receiving NTSC TV signals and with a bit more software work, this unit should be very popular with the ATV crowd. In addition to the TVRX, the DBS_RX has been released. This is a direct broadcast satellite receiver on a chip that covers from 888 Mhz to 2888 Mhz. N4HY has been successful in seeing GPS with it. Gnu Radio has several people participating in a development project for the USRP to produce a software GPS receiver for the GnuRadio software and the USRP. Where this unit really shines is its unparalleled ability to operate on wideband signals. It is clear that the upcoming year will see explosive growth in GnuRadio and its associated hardware projects meeting their potential. The heart of the USRP is a Field Programmable Gate Array (hereinafter FPGA) which does really high speed DSP functions. The data exchanged is done with the computer using a USB 2.0 interface.

DCP-1

John Stephensen, KD6OZH has written articles for QEX on a software defined radio also based on a different FPGA and a different host processor from the USRP. John has a more targeted audience than the USRP since the DCP-1's major goal at the moment is to provide a high speed radio modem for amateur radio use. This modem will be based on Orthogonal Frequency Division Multiplexing (hereinafter OFDM). This has great potential to reinvigorate amateur radio packet radio for myriad applications and increase our utilization of microwave bands. I do not wish to short change the DCP-1 in this report but to point out that it will be features in the HSMM report since it is one of their main activities at present. The DCP-1 will be used for other activities considered later in this report.

LINRAD

For a few years now, Leif Asbrink, SM5BSZ, SDR WG member, has been working on a software package on Linux machines he calls LINRAD. Leif wanted to do software defined radio work in support of some very high performance hardware of his design (call the WSE hardware). LINRAD is a gold mine of software defined radio and digital signal processing techniques that are unique to it. It definitely has the world's best automatic noise blanker. It has various panadapter features which are of great utility in both HF and VHF+ communications. Both the noise blanker and the panadapter have been adopted by Flex Radio for its SDR-1000. Recently Leif has decided that it is time to gain wider acceptance for LINRAD by reworking the software to enable it to support a windowing environment, whether this be Microsoft Windows or Linux or Macintosh. Working with SDR WG members N4HY and AB2KT, Leif has laid down the framework for this to begin. A successful endeavor here would see some truly spectacular capabilities available to a much larger audience than it now currently supports.

In the latest issue of DUBUS, Leif wrote a damning article on modern amateur radio transmitters and the impact of ALC and other nasty features on the spectral purity and occupancy of these transmitters. From the least to the most expensive, almost none fared well. While not strictly an SDR topic, this work was done by Leif using his LINRAD tools and has directly impacted the design of the transmitter in Flex Radio's SDR-1000 software.

AMSAT-DL and AMSAT-NA

AMSAT-DL (Germany) and AMSAT-NA (original group in U.S. and Canada) have embarked on direct use of software defined radio technology. On the upcoming AMSAT-DL's P3E, another in a series of highly elliptical orbit satellites providing many hours a day of articificial ionosphere, the command receiver and transmitter will be a software defined radio and will use some truly spectacular forward error correcting codes to enable extremely weak signals to provide reliable command and control. Known as Turbo codes, France Telecom has licensed their technology for all AMSAT projects.

AMSAT-NA, has gone a step further. For its AMSAT Eagle project, AMSAT has decided that all communications, command and transponders, will be based on software defined radio technology. At the AMSAT-NA annual meeting, upcoming October 2005 in Louisiana, a fully operational "Mode B" software defined transponder prototype will be demonstrated live, on the air. AMSAT will be building a prototype Mode LS transponder using the USRP and the DBS_RX with some help from Down East Microwave. In addition to this work, the USRP will be the basis for a four element phased array transponder prototype on C band, 5.6-5.8 Ghz, in a concept called CC-Rider by its father, Tom Clark, W3IWI. All of these efforts are SDR having pushed the software almost to the antenna and using only one mixer where necessary. Mode B is 435 Mhz up and 145 down. LS is 1269 Mhz up and 2401 Mhz down. In the 5 Ghz

amateur band we have two slots in the amateur satellite service, one up, one down, and they will both be used in the CC Rider project.

Cognitively Defined Radio

SDR WG member Frank Brickle, AB2KT, wrote the first serious amateur radio article on Cognitively Defined Radio in amateur radio circles "Automatic Signal Classification for Software Defined Radios" in the November/December 2003 issue of *QEX*. Let us consider a clear demonstration of the power of CDR and SDR for our purposes. Let us take (as an example) a GnuRadio USRP and the Flex Radio SDR-1000. Consider the GnuRadio USRP hooked to a 20 meter system and capturing the entire band. Its job is to identify and classify signals that look "interesting" in the 20 meter band. After a detailed analysis in part based on the Brickle QEX article and in part on secondary testing after the signal has been classified as interesting in the first test we set an alarm in the computer that says this signal is interesting and should be collected. The computer turns its control attention to the Flex Radio SDR-1000 and automatically programs it for mode, optimal filter setting and begins recording perfect signal with its very large IP3, 1.05 shape factor receiver filters, and more than 100 dB of real dynamic range. This signal is then demodulated, recorded, or further analyzed. This sounds complicated and it might be for the programmer, but imagine the impact such a device would have on an RTTY contest when it can completely automatically find and demodulate ALL RTTY signals that will produce usable print in the entire 20 meter band. This same system can find all SSB signals, tell you which sideband it is, and automatically tune to the correct frequency.

Imagine an emergency situation, where FEMA has several dozen different stations that need to easily interoperate. Software defined and cognitive defined radios would enable FEMA stations to inteoperate and analyze entire bands to find optimal frequencies to conduct their communication where the transaction can be started and stopped using automatic link establishment protocols. Amateur radio can easily do these kinds of experiments and will be doing them in the coming months.

SMART ANTENNAS

Suppose we have four antennas and we can put them up in some configuration. Not necessarily a perfect four-square but some reasonably arbitrary configuration. Using the USRP, and known targets for training, we could constitute a completely software defined radio with smart antennas which would automatically null interferers and/or phase the antennas for gain. The decision, based strictly on signal-to-(noise plus interference), could be completed automated. Another application for this smart antenna technology may consider using the 4 channels of the USRP with four spaced antennas, at a single site, on the FM broadcast band. Suppose we tune to an over the horizon and otherwise undetectable FM station frequency. We will be attempting to detect signals bouncing off ionospheric phenomena such as aurora or sporadic E clouds. This will not give us just a detector for the presence of these phenomena. It will, through the use of

smart antenna and SDR technology, allow us to actually give the location of the reflecting ionospheric cloud.

Summary

Some of the highlights of this year's Software Defined Radio work have been presented. There are other smaller projects not mentioned here that are making contributions to the state of the art in amateur radio circles. This list of things well known to SDR WG members is a highlight of the spectacular technical work happening now, some of it state of the art in all circles, is a thing amateur radio, and the ARRL may be proud of.

Respectfully submitted
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Chair, SDR Working Group.