By Mike Marcus, N3JMM/7JIAKO

Linux, Software Radio and the Radio Amateur

How software radio technology might revitalize experimentation in Amateur Radio.

For a long time there has been concern about the decline of experimentation in the Amateur Radio community, the impact of this on the demographics of the community, and the possible impact on the regulatory situation of the Amateur Radio Service (ARS).[1] Advances in electronics, some pioneered within the ARS, have led to widespread use of technologies that are beyond the hardware implementation skills of most hams without a professional engineering background. Indeed, the title of this article is inspired by an article written nearly 50 years ago by John Costas, K2EN. John feared that widespread use of SSB would lead to a rapid decline in HF equipment building by hams and a consequential adverse impact on the ARS.[2] The thesis of this article is that a well-conceived strategy for using software radio technology in the ARS might have a positive impact on reversing the apparent decline of experimentation and might even bring a new, younger, and experimentally motivated group into Amateur Radio.

What is Software Radio?

A software radio is one in which one or more transceiver functions are performed by digital circuitry under software control on a digital representation of the signal.[3] Software radios use digital signal processing (DSP) for filtering, modulation and demodulation of signals within the radio. While DSP can do everything an analog radio can do, it can also do functions that are difficult or impossible for analog radios. But more importantly, software radios are related to the computer software revolution that is affecting our society. The design and implementation of these radios involves the technical skills that stimulate great interest in today's younger generations.

A good example of a software radio is the DSP-10 2-meter transceiver that has been developed by Bob Larkin, W7PUA, and which has been available in kit form from the Tucson Amateur Packet Radio (TAPR) organization.[4] This radio implements a 2-meter transceiver with DSP and makes the source code available for modification by users.

Just as personal computers use both hardware and software and can be modified by adding or modifying software, software radios can acquire new functionality throughout their hardware lifetime if new or modified software is used. No need here for the old soldering iron!

In the brave new world of software radios, ham experimentation would involve writing software to perform transmitter or receiver functions, modifying existing software to "tweak it," or reading about a new software program, downloading it, and trying it out over the air. I believe that this type of experimentation can generate new interest in ham radio and develop skills that are valuable in today's society.

Present Barriers to Software Radios

While some innovations in ham radio technology might have been slowed by

[1]Notes appear on page 35.

FCC inaction, that does not seem to be the case here as present FCC Rules appear to enable both the use and sale of software radios. The previously mentioned pioneering work by TAPR shows this policy in action. The major barrier seems to be lack of interest in the ham radio manufacturing community towards making a radio that allows users to have meaningful interaction with the software.

A check of ads for top-of-the-line ham transceivers will show that most of them already have computer interfaces and many of them already claim to have DSP. So what's the problem? The problem comes in the words "meaningful interaction" that were used previously. Today's computer interfaces allow one to tune the radio and change modes via a computer—just like turning the knobs. They do not allow you to actually rewrite any of the software in the radio.

Consider the following simple example: Both traditional radios and software radios usually have receiver filters with a variety of bandwidths. In a traditional hardware radio this is achieved with a crystal filter or mechanical resonator for each bandwidth. In the software radio, a mathematical algorithm is used and a set of variables determines the filter bandwidth and shape. Change the variables and you change the bandwidth and shape.[5] Yet no ham manufacturer today allows users to change this functionality! The only commercially available model of which I am aware that allows user modification of internal software is the Australian-made WiNRADIO 3000-series receivers.[6] But this is only a receiver and the DSP in it is done on audio signals after all the tuning, IF filtering, and detection is performed with analog circuitry.

I have had discussions with several ham manufacturers on the issue of software radios for ARS. Several points have kept recurring in these conversations. First, manufacturers have expressed concern that software development by users will require access to manufacturers' proprietary software.[7] The manufacturers probably have legitimate claims concerning the intellectual property in their products for specific functions: for example, downconverter, demodulator and the overall architecture of their software implementation. But one wonders if they are pressing this view of intellectual property in order to maintain or slightly improve market share in the decreasing overall ARS hardware market. Perhaps after reading this article the whole ham community will think about how reinvigorating the ARS might reverse trends and grow the ARS hardware market by attracting a new type of ham.

However, the intellectual property argument doesn't explain the inability to load filter constants into any present radios. Changing filters is not writing a program: It is just downloading to the receiver a set of constants that are used by programs. The explanation for this shortfall probably lies in the remaining concerns.

The second concern expressed by the manufacturers is the issue of user support. Ham equipment is sold with a relatively small budget for user support and manufacturers cringe at the thought of getting calls from purchasers who are trying to get their new SSB demodulator program to work and keep having problems. They have a valid point here. They don't want to ruin their reputation with a user support problem that is impractical. However, I have a suggestion here and I'm sure others might think of alternatives. Sell the radio without the hardware interface and software documentation needed to change the software in the radio; then enlist a few technologically advanced ham groups to be the sole distributors of the hardware/software package. Hams would buy the package from the ham groups and the ham groups would provide user support in the best tradition of the ARS.[8] To save people from themselves, I suggest that any such transceivers have a reset button that resets the software to factory settings so no one can complain that his radio has lost all functionality.

The third point raised is that hams aren't interested in developing and maintaining the software for such radios. I respond to this by pointing out the well-documented DSP-10 2-meter software radio and the new GNU Radio project. Check it out on the Web at **www.gnu.org/software/gnuradio/gnuradio.html**.

You probably have been wondering why Linux is mentioned in the title of this article. GNU Radio, a free software project that is being sponsored by the Free Software Foundation, is a cousin of Linux, the open computer operating system. At present, GNU Radio is a software receiver, not a transceiver. But the principle has been established for using Linux-style development for software radios. A few years ago computer hard-

ARRL's Active Role in Software Radio

Early in 2002, the ARRL leadership appointed a Software-Defined Working Group to press for development of some of the things for which Mike calls, and more. The group, Chaired by Bob Larkin, includes Leif Åsbrink, SM5BSZ; Gary Barbour, AC4DL; Paul Rinaldo, W4RI; Gerald Youngblood, AC5OG; and yours truly. Mike participates *ex officio*. We filed our first report with the ARRL Technology Task Force in July 2002. You can view it on the Web at **www.arrl.org/announce/board.html**. Look for the link to the July 2002 committee reports.

It is true that manufacturers could have done some of the things Mike suggests a long time ago and he rightly points out obstacles to their doing them. That's not stopping some experimenters, though! At least four Working Group members have published articles on software radio and have produced working units. Others from around the globe have been coming out of the woodwork with their designs. A short bibliography for those who want to see what's cooking appears at the end of the article.

Some ham transceivers have had the ability to alter software by plug-in card (Kachina) and flash ROM (Ten-Tec); however, users have not been able to obtain source code to write their own embedded software. Support issues aside, I can safely state that such software—usually written in assembly language, the native language of the DSP in use—is so critical of timing and other issues as to be difficult to write, even for the best of us. That is where discussions of software interfaces begin.

For example, we recognize that a radio having a high-speed digital interface could pass digital samples to and from an external processor. Software development could then proceed on whatever platform is convenient, such as a personal computer. Sound cards also provide the means for easy data acquisition, as amply illustrated in some of the articles listed below.

Beyond that, we see it is possible to construct modular DSP software that would allow users to build block diagrams of their favorite configurations while leaving all the heavy number-crunching inside the radio. Flexibility is the name of that game.

We can expect some really neat capabilities to arise from current work percolating along those lines. Sure, we have bemoaned the decline in experimentation and homebrewing; but the level of circuit integration available from semiconductor manufacturers is actually making things easier in many ways, even if you don't use digital electronics. If you haven't dug into it lately, you're not getting the real picture. Check it out!—*Doug Smith, KF6DX, Editor,* QEX: Forum for Communications Experimenters; **kf6dx@arrl.org**.

ware manufacturers couldn't understand the Linux concept and were concentrating on more traditional operating systems. Many have now accepted Linux and its freeware concept as a valid player in the personal computer area. Perhaps ARS manufacturers might have a similar conversion, especially if consumers encourage them.

Near-Term Steps

There are several near-term steps that could usher in the movement toward ham use of software radio and the consequent changes to the ARS. One might be for someone to just manufacture the DSP-10 2-meter software radio. It is available in kit form, but kit building is almost a lost art and most young people have never heard of Heathkit.

Another near-term step might be for manufacturers to include in their radios, or offer through technically oriented ham clubs, digital inputs and outputs for audio and IFs at audio-like frequencies in a convenient interface such as USB or Firewire.[9] With such input and outputs, hams could experiment with digital processing outside of the transceiver without being forced to send the signal to and from the receiver in analog form and introducing distortion in multiple A/D and D/A conversions. This external DSP could be done without access to the DSP within the radio and avoids proprietary information issues.

As previously mentioned, allowing hams to change the filter constants in receivers would be another promising first step that would not compromise any proprietary information of the manufacturers. Yet this would expose hams to the full reality of today's digital filter-design programs.

A full software radio with user access to the software should be a midrange goal because of its potential impact on the ARS. I urge manufacturers to work with ham groups to explore this option in detail and see whether their present concerns need be long-term barriers. I also urge hams to think about these issues, consider joining development efforts such as at TAPR and GNU Radio, and communicating their views to the manufacturers and the leaders of ham organizations.

Summary

In summary, DSP technology might have a broad impact on the future of the ARS if hams can access hardware that gives them flexibility to experiment and rapidly share software for new design features. However, present trends in manufactured equipment make the commercial availability of such hardware doubtful in the near future. An effective dialogue between hams and the manufacturer community on this topic might lead to mutual benefits.

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Note: The views presented here are those of the author and not necessarily those of his employer.

Recent SDR-related Articles

R. Green, VK6KRG, "The Dirodyne: A New Radio Architecture?" *QEX*, Jul/Aug 2002.

J. Scarlett, KD7O, "A High-Performance Digital Transceiver Design: Part 1," *QEX*, Jul/Aug 2002.

G. Youngblood, AC5OG, "A Software-Defined Radio for the Masses," *QEX*, Part 1, Jul/Aug 2002; Part 2, Sep/Oct 2002.

L. Åsbrink, SM5BSZ, "Linrad: New Possibilities for the Communication Experimenter, Part 1," *QEX*, Nov/Dec 2002.

D. Smith, KF6DX, "Introduction to Adaptive Beamforming," *QEX*, Nov/Dec 2000.

C. Ping, BA1HAM, "An Improved Switched-Capacitor Filter," *QEX*, Sep/Oct 2000.

For further information visit **www.arrl.org/tis/info/sdr.html**.

Notes

[1]The Amateur Radio Service uses generous spectrum allocations that it has received to further the five goals enumerated in 47 CFR 97.1. While these goals have been around for a long time, increasing demands for spectrum from many sectors makes defense of existing allocations vital. One might model the current allocations as a social contract between the government and hams, with resulting mutual obligations. Contributing to the advancement of the radio art is one of the five goals.

[2]John Costas, "Poisson, Shannon, and the Radio Amateur," *Proc IRE*, Dec 1959. The connection between this article and Costas' concern about the fate of ARS was given in private communication with the author. Among other things, Costas was trying to advocate suppressed-carrier double sideband because it was simpler to build and had overall throughput comparable to SSB according to his analysis. This article is also viewed as a key milestone in the development of CDMA cellular radiotelephone technology as it foresaw the efficiency of that technology.

[3]General sources of information about software radio technology and its implications are **ourworld.compuserve.com/homepages/jmitola/** and **www.sdrforum.org/** as well as Chapter 18: "Digital Signal Processing," *ARRL Handbook for Radio Amateurs.*

[4]Bob Larkin, W7PUA, "The DSP-10: An All-Mode 2-Meter Transceiver Using a DSP IF and PC-Controlled Front Panel—Part 1-3," *QST* Sep-Oct-Nov 1999; text available at **www.arrl.org/tis/info/sdr.html**. The TAPR site for information on this project including kit availability is **www.tapr.org/tapr/html/dsp10.html**.

[5]The variables are numbers that define the impulse response of the filter and therefore its frequency response. Given a frequency response and the sampling rate in use, anyone could design a new set of variables using public-domain programs. One possible application of changing filters externally might be to design a filter in real time to counter QRM and improve reception.

[6]**www.winradio.com/home/sdk.htm**.

[7]Note that the microprocessors usually used for DSP are very different than the ones used in personal computers and have been optimized for the specific functions they need to do.

[8]In the early days of the personal computer, industry user groups were key to the support of new hardware and software. This might also be a good model for technologically advanced software radios.

[9]Although we generally use IFs at frequencies such as 455 kHz and higher, an IF can be at any frequency greater than half the bandwidth of the signal involved. Thus a 10 kHz IF could handle most ham modulations and would allow signals to be manipulated by hardware designed for audio applications. A 10 kHz IF may seem untraditional, but in theory and in practice it can work quite well!

Mike Marcus, N3JMM/7J1AKO became interested in radio in high school and finally got a Technician license in 1991 with the encouragement of his father-in-law, Arnold Halpern, W2GDS. He is an electrical engineer and has worked for the federal government for more than 20 years in the spectrum management area. Also licensed in Japan, which he often visits, he uses 2 m and 70 cm there for language practice and has carried his HT to the top of Mt Fuji for some QSOs. He can be reached at **n3jmm@aol.com**.

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