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FlexRadio Software Definable Radio

Now Available to the Public

By John Catalano

In a recent series of feature articles in *Monitoring Times* (See issues Aug, Sept. Oct. 2004) we gazed into the future and attempted to see where radio technology was headed. Although many new technologies are being developed, one that stands out as important to all facets of radio communications – military, cellphone, professional, emergency, law enforcement, aircraft and ham – is SDR, the Software Definable Radio.

Military and government agencies have had access to this developing technology for a while. However, FlexRadio Systems has produced an SDR that it is selling to the public. As far as I can determine, this is the *world's first* SDR that anyone off the street can buy.

Before we launch into the FlexRadio System's product, let's do a quick review of the SDR technology. If some of the following looks familiar it is because much of what we will cover here is distilled from the series of feature articles, "Radio in the 21st Century."

❖ Software Definable Radios

SDR is as important to 21st century radio communications as the superheterodyne was to the 20th century radio. Simply put, SDR moves radio design from dedicated analog-based circuit hardware to software configurable digital data processing. This shift to the digital world allows all signal manipulation to be performed as math transforms. In theory, the radio can be anything we want it to be, just by loading new math functions without any new hardware! From a single channel to a spread spectrum transceiver – Just think of the possibilities!

The ideal requirements for a complete SDR as seen in Figure 1 are:

- Digitize the RF signal right from the antenna to the speaker.
- Make ALL functions of the transceiver, including frequency range, frequency agility, mode of operation, modulation methods, encryption (if any), and display, totally software controllable and definable.
- Hardware independent of system-level programming methodologies.

When these conditions are met, the ultimate SDR goal of one radio that does it ALL – military, cellphone, professional, emergency, law enforcement, aircraft and ham communications – will be a reality. We are closer to that day than you might think.

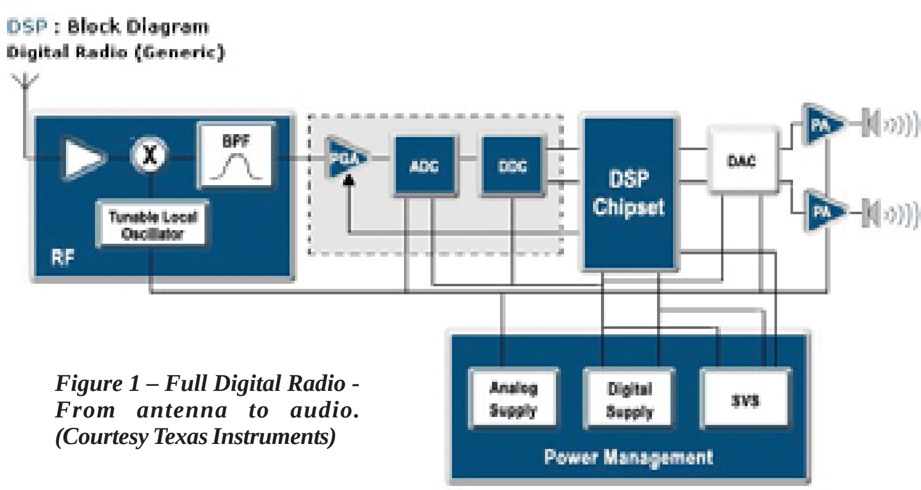

Figure 1 – Full Digital Radio - From antenna to audio. (Courtesy Texas Instruments)

❖ Basic SDR Pieces in Place

Today we have the benefit of a number of technical developments, which make SDR a viable reality. First, we now have gigahertz speed digital integrated circuits, microprocessors, and high levels of complex circuit integration on a chip. This allows for whole systems to be built on a single chip (System On Chip). Secondly, semiconductor manufacturers are producing radio frequency integrated circuits at low cost commodity prices. So now SDR-enabling technologies exist at affordable prices.

❖ Today's SDR Crowd

Although the military applications for SDR are pretty tough, many feel that the cellphone industry presents the greater design challenge. First they have to be backwards compatible with all existing formats: CDMA, CDMA-2000, GSM, D-AMPS to name a few.

A group called the SDR Forum **http://www.sdrforum.org** is steadily gaining membership among the hundred plus companies working on SDR. The forum's members include military communications, cellphone and professional communications companies. All are working to break down radio communications paradigms of the 20th century.

❖ SDR Egg Hunt

In GNU Radio's own words, "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." The minimal hardware referred to is not exactly a simple one chip printed circuit board. It is, as expected, a sophisticated collection of high speed Analog to Digital and Digital to Analog converters (ADCs and DACs) and programmable logic.

The GNU radio's goal is transceiver operation in all ham bands – HF, VHF and UHF up to 2.4 GHz. Currently, the hardware's maximum bandwidth is 6 MHz with a capability of extracting up to four separate channels simultaneously.

From their website **http://www.gnu.org/software/gnuradio**, the project appears to be in the early beta-testing phase of the hardware/software interfacing of the main board with other required modules which are in various phases of development from concept to testing. The GNU project is a great SDR ground-floor learning experience. It requires building and testing various hardware boards, gathering the software as it becomes available, and lots of patience.

❖ Enter FlexRadio Systems

Now what about those of us who are not part of the defense industry or do not want to wait and hunt for the SDR pieces? Is there a company providing an "out of the box" software definable radio? The answer is yes. FlexRadio Systems has released an SDR transceiver model SDR-1000. (Contact information: FlexRadio systems, 8900 Marybank Drive, Austin, TX 78750; 512-250-8595; sales@flex-radio.com, **http://www.flex-radio.com**).

The cost of the SDR-1000A ASM/TR is $875 plus shipping. A receive-only version, the SADR-1000A ASM/RO, costs $676 plus shipping. Keep in mind that, right now, you cannot get another SDR on the consumer market at *any* price.

❖ What Does An SDR-1000 Do?

The SDR-1000 Software Defined Radio transceiver comes with all the hardware and software that currently allows it to perform as an 11

Figure 2 – SDR NOW! The Front Panel of the SDR-1000. Not much to look at.

kHz - 65 MHz general coverage receiver. Currently implemented are the following receive modes: AM, Sync AM, USB, LSB, DSB, CW and FM narrow. Filtering for DRM mode is included; however, the commercially available DRM software is required for decoding. A transmitter function that covers the 160 meter to 6 meter ham bands with a 1 watt peak envelope power (PEP) output in the common ham modes is also included.

Remember, the functions of an SDR are defined in software, so they can be modified or added to much in the same manner that the BIOS in your PC can be updated to add new features. Of course, the as-designed hardware must be capable of supporting the features.

In order to encourage software development, the SDR-1000 uses open source software code for programming the digital signal processing chip (DSP) and its control software. More about the downloadable software currently available later.

❖ A True Black Box

The SDR-1000 is housed in a black metal enclosure (Figure 2) measuring 10"W x 81/2"D x 4"H (25.4cm x 20.8cm x 10.2cm). It requires a 13.8 vdc power supply capable of providing 1.25 amps. The higher current requirement is probably required by the 1 Watt transmitter section of the SDR-1000.

There is lots of space in the enclosure for future hardware upgrades such as a 100 watt transmitter linear amplifier, two meter transverter and automatic antenna tuning units. The square on the front panel is a vent for a future fan, required when all the add-ons are in the box. The SDR-1000's front panel is simplicity itself with just an on-off switch.

❖ How Does It Do It?

The simplified block diagram of the SDR-1000 can be seen in Figure 3. Starting from the antenna, it first consists of a band pass filter (BPF). We require amplification of input signals over a relatively wide range of frequencies (11 kHz to 65 MHz). Therefore, the BPF is designed to remove all input signals except those which lie near our tuned frequency.

Next in the signal processing chain is a key element, the Quadrature Sampling Detector. Very, very simply stated, the Quadrature Sampling Detector samples the incoming RF signal at four times the carrier frequency and directly converts the signal to a baseband (for the old timers, think IF) frequency. The direct digital synthesis chip (DDS) and the 200 MHz jitter clock oscillator provide the QSD with a wide frequency coverage with very low phase noise.

As the name implies, the circuit uses four capacitors to sample the RF signal at four different times in a cycle of the input signal. This occurs at 0, 90, 270 and 360 degree phases of the signal. This results in the RF carrier being mixed to baseband frequency.

Additional filtering results from the antenna impedance and the sampling capacitor, which form an "RC" filter (a high or low pass filter using resistance and capacitance). The four capacitors provide the detector with four (Quad) different phased outputs. Combining the 0 and 180 degree-phased signals results in the "I" output. Likewise when the 90 and 270 degree outputs are combined, the result is the "Q" output. See Figure 3. Believe it or not, these two signals contain *ALL* the demodulated signal information. This is where the PC's signal processing comes into play.

❖ Mind Your "I"s and "Q"s

In order to provide the SDR receiver with a wide dynamic range, the output of the QSD must be matched to the input of the computer's sound card with a minimum of added noise. This is no simple matter, and it can greatly affect the performance of the SRD receiver. Figure 3's simple amplification blocks coupling the output of the QSD to the PC sound card belies the complexity of the problem.

With the addition of the RF Expansion Board (RFE), which is not shown in Figure 3 but is in our SDR-1000, Flex Radio claims an impressive 90dB, two-tone, third-order IMD dynamic range and -141dBm MDS in a 500Hz bandwidth. In order to achieve these specs, they must have gotten all the hardware subtleties right.

The "I" and "Q" outputs are connected to the computer via the left and right stereo Line In channels of the sound card, and the signal processing program running on the PC takes over. Be aware! As we shall see in the next part, not all sound cards are created equal nor are up to the SDR1000 requirements.

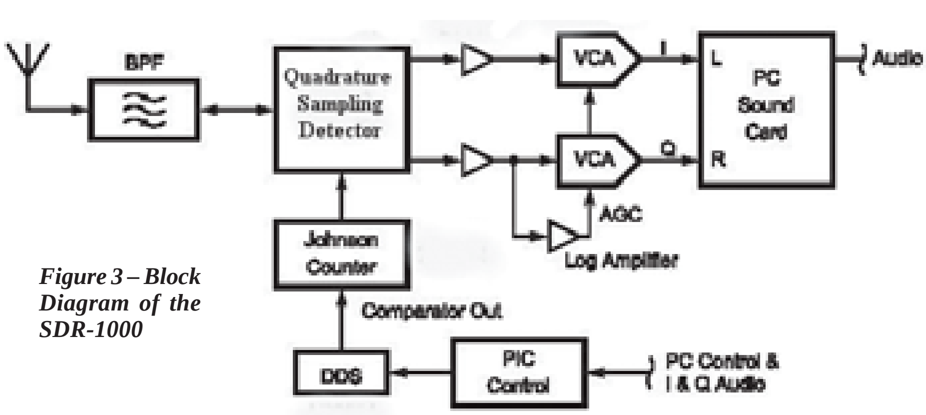

Figure 3 – Block Diagram of the SDR-1000

❖ Hardware Requirements

The PC required by the SDR-1000 is not exactly a lightweight. First, from my experiences, it *must* be running a Windows XP operating system. The FlexRadio instructions say that Win 2000 is also supported but I did not try it. I did try Win98 SE and had all sorts of major problems that cleared up upon going to XP.

As for the PC hardware, an 800 MHz processor is suggested as the minimum. I have found that a 500 MHz Pentium III worked as well as a 1000 MHz Pentium 3. With the 500 MHz Pentium III, CPU usage while running the PowerSDR Console (Beta 0.1.2) program varied from 29% (Spectrum Display OFF) to 98% (Spectrum Display ON). You will need a minimum of 256 MB of RAM. Since the SDR1000 is controlled via the parallel port, your PC must have a full 23 pin parallel (printer) port.

Finally, the PC must have a "high quality" sound card. Remember, as we saw above, the dynamic range and distortion performance of the SDR-1000 is a function of the quality of the sound card. FlexRadio lists a number of cards which they have tested and verified work with their software. These include: Turtle Beach Santa Cruz (PCI), SoundBlaster: Audigy2 (PCI), Audigy2 ZS (PCI), Audigy2 LS (PCI), Extigy (USB), and MP3+ (USB) . It is specifically noted that the Audigy2 NX USB is not supported.

Not all PCs have Line In jacks, especially the newer laptops. These require a USB sound system such as the SoundBlaster Extigy or MP3+.

The modified IBM 300 GL PC that we used had its sound card included on the motherboard. The bad news was that this proved to be totally unusable with the SDR1000 software. It resulted absolutely nothing but noise, much of it random and loud. All manners of mixer and driver settings were tried over a number of days without any success. But to be fair to Flex Radio, they warn SDR1000 users right up front that only certain soundcards work.

The good news is that the installation of an inexpensive Aureal Vortex PCI sound card, circa 1999, worked perfectly. First, however, the on-motherboard sound had to be disabled in the BIOS setup. Win XP recognized the Aureal sound card and loaded the required drivers. Then WWV's beautiful second ticks began streaming from my speakers!

❖ Next Time in Part 2

In Part Two we will hook the SDR1000 to a PC and use the software that is currently available for the SDR1000, PowerSDR Console (Beta 0.1.2) We'll answer some questions I'm sure you have such as, "What's in the Box?" and give you some first-hand, on-air, user impressions. Stay tuned to what may be the biggest event in radio technology for the past 75 years.