# DIGITAL SIGNAL PROCESSING and Amateur Radio

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Tom calls the necessary ingredient magic, and Paul Rinaldo, W4RI, calls the necessary ingredient an incubator[1] [2]. Whatever you choose to call it, we have lacked the necessary ingredient in ham radio to broadly apply the collection of techniques known as *digital* signal *pro*cessing (DSP). The magic in the amateur satellite service has been provided by AMSAT[3]. In the digital communications modes, the incubator was supplied by TAPR[4]. AMSAT and TAPR have joined to support an incubator project to achieve the broad use of DSP in amateur radio.

DSP is a field which has its roots in the mathematics of Newton, Gauss, and Fourier. These people lived hundreds of years ago. Why are we stessing these ancient techniques? Primarily because a much newer technological revolution has taken place which allows us to apply DSP techniques in increasingly complex combinations. Of course, we are talking about computers in general and microprocessors in particular. Until the very recent past, even microprocessor elements were primarily used in proprietary special purpose devices with specific tasks in mind. For example, there are DSP chip sets manufactured by several companies that are totally dedicated to being Bel-212 modems for phone line use.

We will not delve into the theory of Fourier analysis, linear systems, ARMA models, and finite impulse response filters here. However, a little study of these technical topics reveals that we need only do a handful of mathematical operations well. The primary ones are multiply, accumulate, and shift contiguous data locations in memory. If we were to design a processor that did these things well, and ignored a lot of the things general purpose microprocessors are supposed to do, we would open our systems to the power of these DSP techniques. Fortunately for us, we don't have to design these chips. Possibly the best known family of DSP chips today is the TMS320 family of DSP microprocessors (DSP engines). In fact, the three operations above can be combined into *one machine instruction* on the TMS320 family. It is what makes these chips one of the idealized sets for most DSP operations. There are others, including the Motorola DSP 56000 which have recently begun to flow to users of DSP engines. For others, and a general discussions of these chips see[5].

Why should all this excite us? Maybe a few examples are in order. A well known novel, which used DSP techniques to the advantage of submariners, was Tom Clancy's "The Hunt for Red October." The signal processing done in that book enabled the "hunt" to be sucessful. The story was fiction but the techniques on which the plot was based are very real. CAT (computer aided tomography) scans have greatly reduced the need for inherently dangerous exploratory surgery thanks to DSP. However, the funds for research and development have come primarily from the telecommunications industry. The ability to do very complex DSP operations on small devices has greatly reduced the capital costs of maintaining and growing the telecommunications that now surround the globe. The ISDN (integrated services digital network) will be a reality in the near future thanks in a large part to digital techniques.

## BUT WAIT THERE'S MORE

What has this to do with amateur radio? Imagine that on Monday Bob wants to talk to Tom on 20 meters and wants to use ACSSB (amplitude compandored SSB) for a better signal to noise ratio. On Tuesday Tom finds that 20 meters is dead but needs to talk to Bob again, so he will use a voice encoding scheme and send the digitized voice over the packet network between them. But wait, there's more. On Wednesday, Bob wants to transfer a large file that resulted from the previous two days of conversation to Tom and wants to do it at 9600 BPS. But wait, these guys are really active, there's more. On Thursday, Tom wants to gather weather maps from the NOAA satellites. On Friday, Bob wants to talk to Tom but apparently transmitter is acting up and he needs an audio spectrum analyzer. But wait there is more to "DSP week." On Saturday, it's an EME weekend and Bob and Tom want to try getting each others echoes off the moon. Alas! Murphy has struck and both have lost their high power amplifiers. But wait there is more. On Saturday, they decide to try Fuji Oscar 12 PSK packet and its bulletin board in space. A few years ago, you would have said these guys are millionaires or loco since all this can't be done anyway with what we have. Each of these operations is characterized by one important feature

On a DSP chip **IT'S ONLY SOFTWARE**.

ACSSB is almost too easy on DSP engines. LPC-10 and ADPCM (linear predictive coding and adaptive pulse coded modulation) have been around for a while to do encoding of digitized voice. The PSK modems and the WEFAX-APT demodulation are both based on a phase locked loop (PLL) which is straightforward on a DSP chip. The spectrum analyzer and the EME weak signal detection technique both use the same DSP process (FFT) as their basis as decsribed below. In addition to these examples, one you can make modules for all the standard modems and some non-standard modems at least up to 2400 bps on the least expensive of these chips (TMS320C10). The heart of the 9600 bps demodulator can be done on this chip and the transmitter is trivial. On a single generation later the least expensive chip (and still inexpensive) you can do the entire 9600 bps modem. When Texas Instruments finally releases the TMS320C30, you can do a 56 Kbps MSK modem with coherent demodulation (optimal) and have microprocessor power left over to do the entire AX25 protocol and HDLC. This chip, when coded carefully will sport 33 Megaflops (!!) and that is about 3/8-ths of the fastest code N4HY has ever been able to code on a Cray-1.

We have emphasized some fairly advanced applications. In fact, these chips lend themselves very well to the more mundane tasks of filters of many types: complex bandpass, lowpass, and highpass filters of many types are very straightforward on these chips. An optimal and adaptive woodpecker filter that can "tune" to different pecking rates is also achievable on this type of chip. The list of things you can do on these chips is enough to write an entire textbook on digital signal processing and there are books available on these topics[6].

## A Little Magic

To begin this project we are negotiating for 20-25 boards manufactured by Delanco-Spry in Silver Spring, Md. On them is the Texas Instruments TMS320C10-25. These boards fit into a standard long expansion slot on almost MS-DOS based machine (see figure 1). Our final BUT WAIT THERES MORE is that all the functions mentioned in the DSP week above can be done on these boards with high level support from the DOS machine. Some of the software exists and has been tested and is being improved. If it were all done there would be no need for a project and we would concentrate on getting wealthy. We have concentrated our initial efforts on the spectrum analyzer and weak signal work with a great deal of success. The spectrum analyzer is the functional equivalent (with a few less bells and whistles) of a $10000 machine manufactured by a reputable company here in the U.S. When most of us think of a spectrum analyzer, we envision a device which is a tunable receiver slaved to an oscilloscope. The frequency of the receiver is swept and the receiver's detector output is displayed. At any one instant, the receiver is tuned to only one frequency. If the receiver has a given detector bandwidth and we are using some total sweep width, then we can define a useful ratio N to be

$$N = \text{sweep width}/\text{bandwidth}$$

where N is typically 100-200 and is the number of independent frequency channels that are being scanned. On any one channel we spend only $1/Nth$ of the time and our ability to see a weak signal is severely comprimised. In the case of a spectrum analyzer done with DSP techniques, we can choose to have N independent detectors, each of which operates all the time. To do this? we have to take at least 2N data samples of the wideband input signal (corresponding to the sweep width) with a high-speed A/D converter, and then do mathematical magic on the 2N numbers; the magic most often applied is the Fast Fourier Transform (FFT). You make N be some power of 2 (like 128, 256, 512, 1024). With the DSP chips and boards we can now buy for less than the price of a weekend in Los Angeles or an 8877 on 2 meters, N=512 with a channel bandwidth of a few Hz and a total spectral bandwidth of a few kHz is feasible, See figure 2 for a pictorial representation of the two types of analyzers.

If you add up the cost of using special purpose hardware to do the other tasks in the DSP week, you can see that the savings are tremendous and indeed make some of these things possible where they were at best difficult before. The primary example is the EME without high power amplifiers. We hope this project will produce the other things in our DSP week. The structure of the project will follow a set of rough guidelines. We are looking **for** a few people who are capable of writing (or learning to write) TMS320 assembler to write the functional modules that will be used as building blocks. The applications in this project will be controlled in a high level language on the PC. We have tentatively settled on "C" as the natural system language for these applications. Already in use are Borland's TurboC$^{tm}$ and Microsoft's MSC-5.0$^{tm}$ and Aztec "C". We are looking for people who can program "C" to help produce these neat applications for the modules on the board. We also have a place for a few people who will be strictly "users" to critique the efforts of the people doing the coding. As applications become available, we will either publish them or make them available to the amateur community through the commercial vendors in those instances where the vendor either paid for the development by funding the work or acquires a license from the project participants. The commerical route is for those who have (say) a C-64 and want a widget that plugs into their computer and -provides these neat applications. In the case of ACSSB, DSP will provide an easy way to get pilot tone coded compression without! having to adapt someone else's reject boards or modifying your equipment. For packet radio, for the first time we will have adaptive equalization working for us. If you are interested in participating in this project, write or call us and we'll be glad to put you to work! We believe this project will provide exciting new capabilities

**REAL SOON NOW!**


[1] Thomas A. Clark, a talk given at the 1987 Trenton Computer Festival.

[2] Paul Rinaldo, W4RI, "Empirically Speaking", *QEX*, April 1987.

[3] In the U.S., AMSAT, Inc., P.O. Box 27, Washington, D.C. 20044

[4] TAPR, Inc., P.O. Box 22888, Tuscon, Arizona 85734..

[5] Aliphas, Amnon and Feldman, Joel, "Digital Signal Processing Chips", *IEEE Spectrum*, June 1987, pp. 40-45

[6] Rabiner, R. and Gold, B., *Digital Signal Processing*. Prentice-Hall, Englewood Cliffs, N.J., 1975.

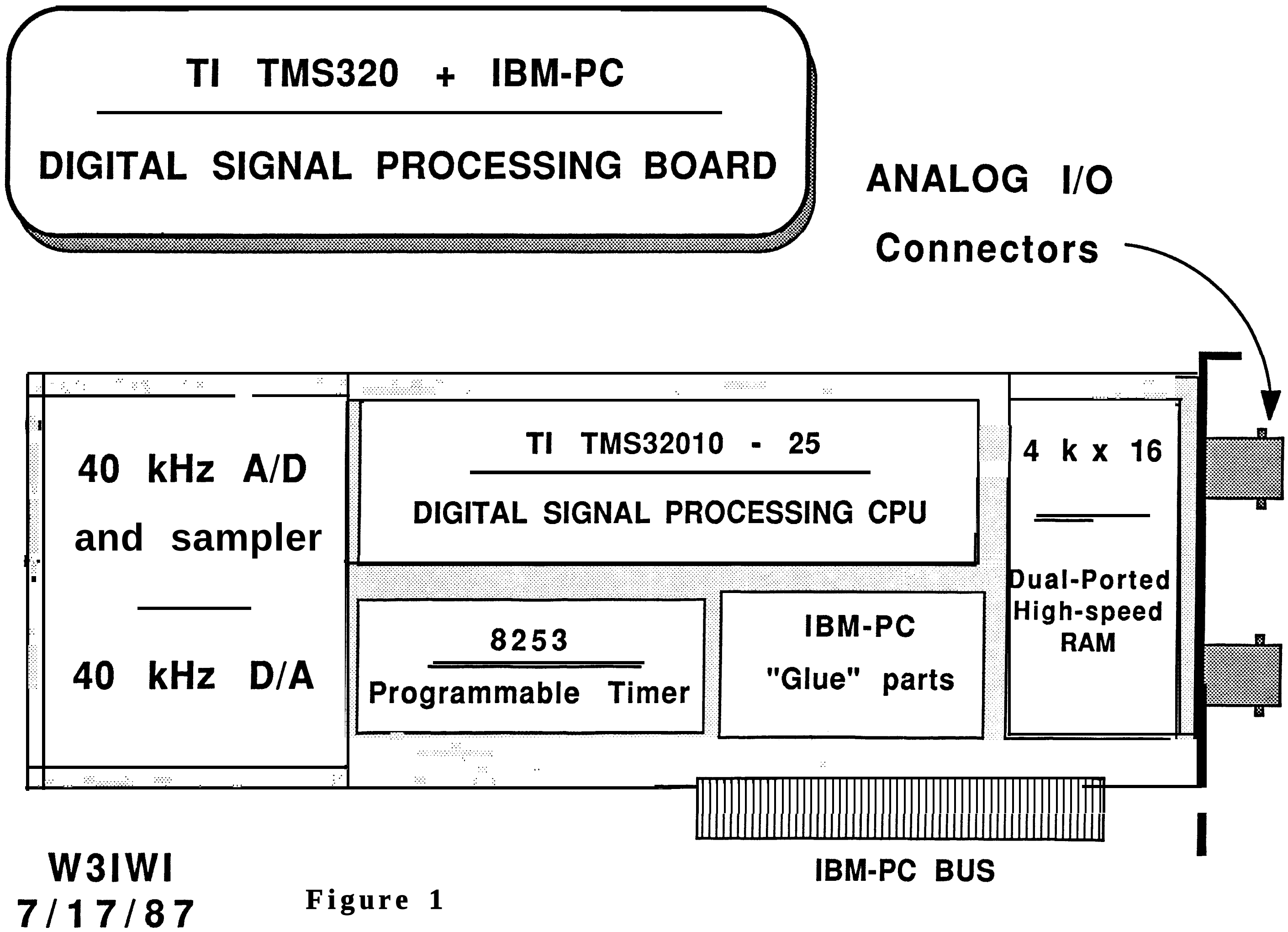


Figure 1

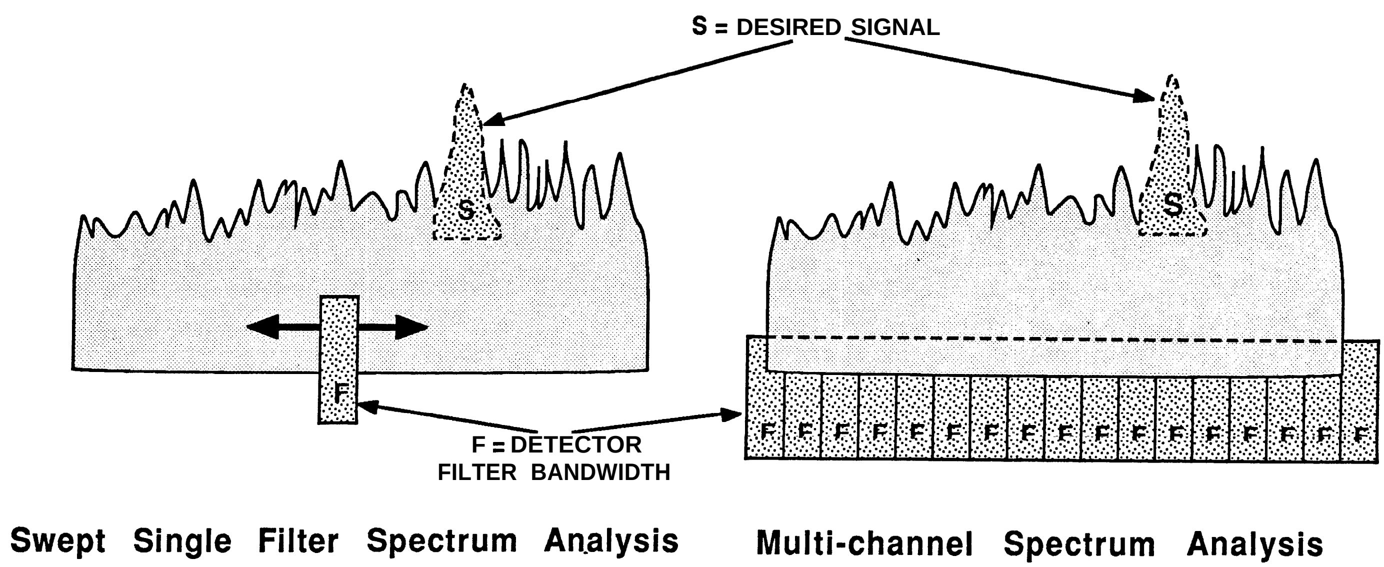


Figure 2