The DSP Project Update

by
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1. Introduction

TAPR and AMSAT have signed a formal agreement which forms a joint project. The purpose is to bring the rapidly advancing technology and techniques of digital signal processing to bear on the communication needs of amateur radio. The AMSAT-TAPR digital signal processing project has made steady progress over the past year on both software and hardware. Lyle Johnson is leading the hardware effort in Tuscon and will report on that progress elsewhere in these proceedings. We will report on work that is ongoing to choose what the second generation DSP unit will look like.

The project has been very lucky to have several new people come along and offer valuable suggestions and in a few cases some new software. Motorola, Inc. and A.T.&T., Inc. have donated development systems, none of which we have running at the time this is being written but all within days of being handed to the project. The project has acquired the use of complete development system and software for the TMS320C25, T.I.'s current best that is available for OEM's 'over the counter.' That acquisition is a story that will amuse you and that will be covered. The TAPR-AMSAT project, whose current planning and future goals you will be told about here, believes strongly that we are leading amateur radio into new possibilities for special purpose communications modes being as easy as RTTY and packet and thus involving many more people in these areas of our fascinating hobby. Indeed in some cases, this could raise the involvement in many of these speciality modes significantly.

2. Software Developments

At the last networking conference, we reported on the spectrum analyzers and a modem for the reception of JAS-1 or FUJI OSCAR 12 and about ongoing software work at that time (1)(2). The work continues to emphasize modems and applications, of fast fourier transforms which are at the heart of our spectrum analysis tools. All software efforts in the past year have been on either the DSP-10 boards the project acquired from Delanco Spry (3) or on the PC-clones in which they run. The FUJI Oscar 12 modem took on a new guise which has been very effective in demonstrating the functional versatility of DSP approaches to communications systems. We decided to add a BEL-202 modulator following the 1200 bps PSK demodulator. This enables one to copy the signals from JAS-1 with the DSP board and an unmodified tnc. We will be using this piece of software a great deal in the coming months after it has been modified to run on a dedicated DSP box the project will produce for the benefit of amateur radio. In the early part of next year, PACSAT 1,2, and 3 will be launched. PACSAT 3 will have a CCD camera on board as its primary mission. All of these satellites use PSK on the onboard transmitter at rates between 1200 bps and 4800 bps. The DSP software will support these satellites as the demodulators. The uplinks are Manchestered FSK with the rates as before. This is also easy to produce and will be part of the software work that will be available for distribution with the initial units.

N4HY also has working a Hilbert transform demodulator, of the type mentioned in last years proceedings, in DSP56001 'C' code and less optimal versions in TMS32010 code (due to smaller data space) which demodulate QPSK at rates up to 9600 BPS, BPSK to 4800 bps, coherent demod for GMSK to 4800 bps all with the same carrier and data extraction loop. The only change is the input of the minimum allowable phase transition during bauding. The data decision algorithms differ considerably from one type modem to the next but the same basic element is common to all these modems. In some cases, filter coefficients have to be changed (change a couple of dozen numbers in the data) to allow for different width spectra, etc. The common thread in the demodulation of phase modulated data signals is never more apparent than when the demodulators are written in software. The DSP56001 is fully capable of going faster than the numbers mention above, but these are the upper limits due to the TMS32010.

N4HY and KA9Q worked on DSP and PC software that does OSCAR 13 PSK telemetry modem functions and also does decode of the telemetry frames from the spacecraft. This was used to monitor tank pressures, battery voltages, and many other critical values relating to the health and welfare of the spacecraft during the critical engineering phase immediately following launch. The modem works well to small signal to noise ratios now but could use some more optimization of the parameters which control the phase locked loop which is at the heart of the system. Both the Oscar 12 and 13 modems are based on the Costas Loop demodulator (4). The work remaining to be done is the optimization of the numbers in the program which govern the dynamical behavior of the 'loop filter' which determines its response to various phase and frequency error it is trying to eliminate. This should allow the DSP modems to work down to smaller SNR in the case of Oscar 13. The dynamical behavior of the loop needs to be different in the case of high doppler and high SNR such as will be the case in the PACSAT's to be launched next year (5)(6)(7).

Two approaches to be1202 demodulators have been attempted. One is a PLL used as an FM demodulator and the other is a filter discriminator modem. The first attempts to track the frequency variation as the signalling changes from one tone to the other. The latter divides the passband into two parts by using a pair of filters. Bit decisions are based upon which filter shows a higher energy content. The former allows for much better data carrier detect to be built and the latter is easier to modify. It can't be too much longer that we will have to deal with these modems as the DSP box and better hardware modems come along to replace them. Nevertheless it is of at least academic interest to determine which of the approaches AFSK can be best done in an inexpensive DSP chip.

One of the most powerful tools that DSP allows us to make is a spectrum analyzer. This has wide applicability to many areas. W5SXD has given us a very nicc EGA display for one of our early fast fourier transform routines. John Connor, WDOFHG has produced a useful DSPSCOPE utility for doing an audio oscilloscope function and it works nicely for examing waveforms. Franklin Antonio, N6NKF probably takes the prize for stirring up the troops as much as anyone. He wrote a routine, based upon the work of Burrus and Parks that runs in the PC along with the display routines. It did a creditable job of running at close to the same speed as one done by the authors of this paper and he uses the Delanco Spry board only for sampling. It is a smaller FFT but the display was autoselect EGA, CGA and could be mouse driven. Investigation by N4HY revealed that Burrus-Parks had the faster FFT's already done in TMS32010 code. They needed quite a bit of changing to run on the different architecture of the DSP-10 but they have allowed real valued signals to be done with one-half size complex FFT's saving time and storage. They are also much faster as they are radix four and radix 8 FFT's with three and two butterfly's respectively. Then a partial butterfly is needed to take the half size complex FFT and get the real signal FFT output from it. This gives us a much more serious tool for spectrum analysis of audio signals. (These are 'real' signals. Those that come out of your speaker are real valued signals). The code that runs on the PC is being optimized to run in hand coded assembler in critical areas where the speed bottleneck now exists. Linear and Power displays are now working along with a variety of other functions. This is a great deal faster than the old routines.

We are also studying in considerable detail, the optimal statistics to be used in weak signal detection problems. W3IWI did a detailed looked at the statistics of the signal returned from the moon. This study along with more recent input from Dick Goldstein of JPL, and Vince Poor (8) of University of Illinois also gave us some detailed input about this problem. 'With the recent success of I2KBD, DSP team member from Italy, in receiving his own echoes from the moon, we are again spurred on to applying this work to the task of truly QRP EME. This technique will not and should not be limited to QRP EME. It can and probably will perform much better along weak signal paths terrestially. It should give VHF-UHF types a tool that will allow QSO's using signals that were previously unusable. The coherence time should be much longer than those returned from the moon and the real power of the FFT will shine in these cases. In the early experiments done by the authors over a 150 mile path on 78 cm with satellite arrays were astounding to say the least. The power could not be turned low enough at N4HY for W3IWI to prevent detection on the screen using a crude display program. This can and should be revisited soon.

Another application of the F'FT based spectrum analyzer has been occupying the thoughts of VE3JF, N6NKF, W3IWI, and N4HY. 0 ne of the great needs in packet radio and HF digital modes in general is a better modem for HF. The general idea is to send more than one tone at a time and encoding more than one bit of data during each baud or signal element. This will alleviate a large part of the damage HF propagation does to a digital signal. The multipath problem causes each signalling element to arrive from a random number of reflectors and all arriving at different times. This can cause destructive interference. If you signal at a slower rate, the likelihood of this multipath distortion causing you to make a decision error goes down considerably. If we encode 6 bits in each signal element and then transmit this at 50 signal elements per second (50 baud), we will be transmitting data at 300 bits per second. Several studies have been done which show that somewhere near 50 baud is nearly optimal for HF digital transmission in the 40 meter and 20 meter bands. This is one of the reasons AMTOR is so successful at getting the data through (along with its relentless retransmission). We need to spend a great deal more time developing this capability as it will be of great benefit to HF digital transmission modes.

N4HY has considered several. specialty modes over the last year. The first to receive a concerted effort has been WEFAX-APT. This is the Automatic Picture Transmission from the NOAA weather satellites. For several years, many reference books (Taggart from 73 and ARRL Handbook) have claimed that a phase locked loop is not the best way to go in copying weather picture transmissions from the low earth orbitting weather satellites. The scheme used by both NOAA (USA) and Meteor (USSR) satellites is to encode the picture element at the current time as the amplitude of a pure tone. For the NOAA birds, this is very close to a 2400 Hz tone, sent into a wideband (70Khz) FM transmitter. When the amplitude is near minimum, the picture is black. When the amplitude is maximum the pixel is white. The same is true for the Soviet satellites with the exception that there is quite a variance in the frequency of the tone from one satellite to another. Most PLL's used in the demodulation of these satellite signals are first order PLL's with very narrow bandwidths in order that recovery of the signal may be done in noise. It would appear that most of them are tuned for the nominal frequency of 2400 Hz used by NOAA. When the Meteor satellites, with their low modulation index for black, are used with these 'mistuned' first order PLL's they do not function properly and the results are poor. Here is a strong case example for using DSP. Nothing had to be changed in the program to make it work PERFECTLY with the Meteor satellites except the frequency. Upon changing one number in the DSP program, the demodulator worked perfectly and the raw pictures one gets with the Meteor satellites are preferable to NOAA pictures since the dynamic range is smaller in the NOAA pictures. This may no longer be true after we begin working on image enhancement for these pictures. The conclusion is that the Meteor signals are phase continuous during the picture even when the modulation falls to small amplitude. A first order PLL will just receive a small error signal during this period and will not adjust the phase. If you have a small frequency error the PLL will just spin through these areas of low amplitude modulation and come out of them with small phase errors at most. This procedure yields several dB of signal to noise ratio improvement over the product detector approach used in so many WEFAX-APT demodulators.

3. Hardware donated, Future DSP projects

The major DSP chip manufacturers have both wittingly and unwittingly been of great aid to the DSP project. Motorola donated two DSP56001's, a boot ROM which includes a monitor, and bare boards for development purposes to our project. The DSP56001 executes 10.25 million operations per second and this number is an underestimate of its real capabilities. The reason is that like the T.I. chip we have been using, it does in parallel those things which make DSP very efficient on these chips. However, of all the second generation chips we have evaluated to date, this is clearly the most capable. Even without careful coding we should be able to run 19.2 kbps without much problem doing both FSK and PSK modems of several different varieties. Lyle Johnson, WA7GXD, and the authors have considered what should be the next step after the DSP-1, which is considered in these proceedings. We believe that we should have a very capable DSP board that will carry the DSP56001 at its heart, which will be available as a replacement card for the TMS32010 board in the DSP-1. Steve Sagerian, KAOYRE, is building the Motorola donated kits for the project. Serious coding will begin on this card once this construction is complete. Steve was also responsible for securing the donation for the project.

NN2Z, Dave Truly, has become well known to many tcp-ip enthusiasts as the current author and manager of the bm mailer program in KA9Q's, net.exe program. Recently, Dave was asked to join the DSP microprocessor support group at ATT. Shortly after joining this group, Dave began pushing the concept of this group donating some hardware and software to the DSP project. The group leader has decided to do exactly that. The DSP-32 development engine with the support software will be donated to the project. Dave is learning as much DSP as he can and will also be working on code for the DSP-32 with N4HY in support of our evaluating the DSP-32. We believe that this will be a useful product for the project to consider constructing.

Companies can sometimes even make unwitting contributions to our efforts. We don't turn them down just because they didn't intend for them to be of benefit! N4HY works at IDA/CRD in Princeton, NJ. He works in the area of signal detection and estimation. Also working there is Maureen Quirk, Ph. D. an engineer specializing in DSP and signals. They are partners on many technical projects. During the spring of this year, N4HY had to go to England for work at the time of the largest gathering of people specializing in signal and speech processing, the annual international meeting sponsored by the Acoustics, Speech, and Signal Processing section of the IEEE. Maureen decided to go to all vendors and gather as much information on DSP chips and the latest products for the benefit of N4HY. While doing this favor, she had a card from T.I. stamped at each vendor of a T.I. DSP chip product. Returning this card enabled her to participate in the drawing for the grand prize. She won. She got the ASDS from T.I. This is the complete software development PC plug in card for the TMS320C25. The memory chips alone, 128K of 25 nanosecond static memory, are pure gold even if they are silicon. She doesn't own a PC. Thinking that she would never use it, she started to give it back. Realizing that their would be death and destruction upon her return and her usual partner finding out about this curious circumstance, she decided in favor of life. The board now has a permanent home in the 386 machine residing at the QTH of N4HY. But of course, Maureen may use it ANY time she wants to!

We will be evaluating these DSP chips for the TAPR AMSAT DSP project and studying the best way to make use of all these resources. With all these development tools at our disposal, we will be able to give a fair evaluation to each of these chips and find the strength and weaknesses of each. This will be reported in the next Networking conference.

4. Future, Pie in the Sky, etc.

If the future of the DSP-1 is as bright as we believe it will be, one of the great benefits such an engine could provide would be as an educational tool. It would be an inexpensive approach to having several different DSP chips along with a host processor to interface with it available on an open architecture for programming. This is ideal for amateur radio experimentation and for educational purposes which are not easily seperable in this case. The current costs for one of these development engines for each of the DSP chips is several thousand dollars. For about the same cost one could have a less capable development system but be able to put many different chip/boards in it for evaluation and comparison. The obvious value to education does not need to be belabored further. This particular project has an audience that greatly exceeds amateur radio as some others have in the past. We are wiser than we have been in the past and are looking at this project as a means to do future projects. The interest in the outcome of this project is demonstrated by major companies *donating* hardware and software valued at several thousands of dollars. The applications are limited by people's imagination and time more than any other factors.

As evidence of growing interest, the IEEE ICASSP meeting for the coming year is in Glasgow, Scotland. This is the next meeting of the group where the TMS320C25 board was won. The authors of this paper have had accepted a paper on the DSP-1 and our project and we will represent our group at this conference next May.

5. People and Conclusions

The people in this project are what it is really about. The array of talents allied against the communications needs of amateur radio is very impressive. We need to thank Courtney, N5BF for beginning to try and give a responsive central location for information on DSP. Paul, KB5MU and Courtney have done a very nice job of producing a schematic of the Delanco board for the internal use of the project members. It has been. invaluable aid in deciding what was done wrong and what was done right. John, WD0FHG deserves a great deal of thanks for his mailings of the DSP diskettes. TAPR is also mighty lucky to have Andy Freeborn, NOCCZ to be president. The value of his aid in managing the DSP project administratively cannot be overestimated. By next year, we should be here telling about all the neat stuff that runs on the DSP-1. We hope several of you will have it in your shack by conference time in 1989. For those who have despaired of progress, we hope that this DSP year in review has enlightened you. We also remind as often as we can, look at the people who are writing the papers on DSP and on PACSAT. The upcoming launch date early next year will not wait while DSP can, no matter how loathsome the prospect is. Whenever you write a report on a years activities in a group as diverse and widespread as this is, you inevitably leave some contribution out that should have been described. If we have made such a faux pas, it was inadvertent. For those of you with access to ARPANET, you may find the entire contents of the DSP mail distribution available in several diskette images. FTP to tomcat .gsfc.nasa.gov with user guest. The DSP diskette images are available in directories DSPX where x is the number of the DSP diskette image. ENJOY and thanks for your support and continued interest.

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