DSP COMMUNICATIONS EXPERIMENT

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Introduction

The laboratory experiments used in a Digital Communications course for students in the Electronics and Computer Technology Programs were changed during the past three years in an effort to improve student's learning experiences. Use of commercial training equipment was discontinued. Students built key parts of circuits and combined them with laboratory test equipments. In Fall07 a signal-processing experiment was added. Students were introduced to the use of Fast Fourier transforms in an interesting application, software-defined radio.

Background

In prior years much of the laboratory work for this course had been based on the use of function modules. Students observed signals produced by module circuits at test points using general-purpose test equipment including spectrum analyzers, function generators, and oscilloscopes. Many different types of digital and analog modules are available in the laboratory. Manuals for each module covered the theory and operation of the circuits. Detailed descriptions of experiments were also included.

In prior years students in the digital and analog communications courses had experienced difficulties using the modules. They said that many circuit details were not available in the schematic provided on the module top surface and that they were uncertain about some of the details of the operation of circuits within the modules. When students failed to get proper results they often blamed the modules. Students did not seem to be gaining as much as they should from the laboratory experience. It seemed that alternatives needed to be explored to be investigated.

Improving the Experiments

During the past three years of teaching the digital communications course new lab experiments were developed which did not use the function modules. In these experiments students built and tested circuits (examples in Figures 1, 2) in which the digital functions were implemented in integrated circuits. In a first effort experiments in the laboratory manual provided by Beasley et al[1] were used.

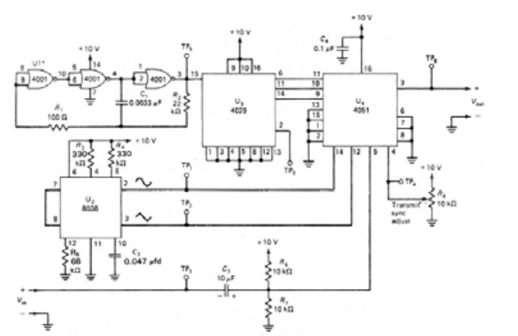


Figure 1. Time-Division Multiplexer

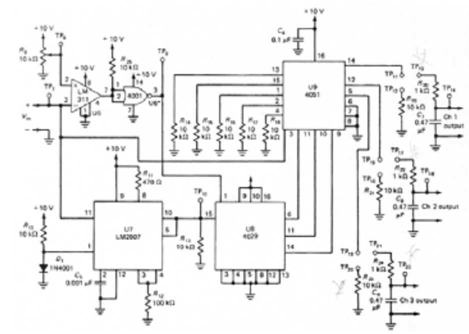


Figure 2. Pulse-Amplitude Modulator

There experiments were excellent. Students made many positive comments. They appreciated being able to construct and test a significant circuit application. A negative was that students spent a quite a bit of time troubleshooting the circuits, mostly due to wiring errors made when they assembled the breadboard.

To address the trouble-shooting issue the experiments were modified slightly reduce the complexity of the breadboard. The oscillator part of the circuit was implemented using a function generator (Figures 3, 4, 5). That reduced both the number of components and the time spent trouble-shooting. More time was available to study the key function and observe results due to changes.

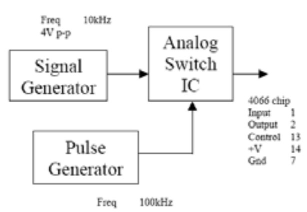


Figure 3. TDM

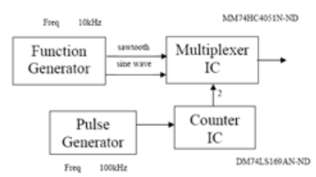


Figure 4. FDM

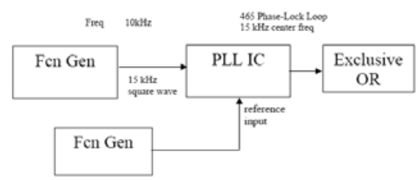


Figure 5. PLL

There are now six lab experiments for the course as listed below. The time to complete each experiment varies, but most involve two or three lab class periods.

Pulse Amplitude Modulation
Time Division Modulation
Pulse Width Modulation
Smith Chart
Phase Lock Loop
DSP Experiment

DSP Experiment

The DSP experiment involved amateur radio signals, Fourier Transform and digital filtering. Work on the experiment started in late summer and it was performed by students in the Fall07 semester. A brief description of the technical basis of the experiment follows. The details are too lengthy to present in this paper. In four papers Gerald Youngblood[2,3,4,5] provided an excellent description of the technology. These papers and Youngblood's recent PowerPoint presentations[6,7] were very helpful.

The experiment involves synchronous detection of radio signals. The incoming radio carrier and information signal are mixed with the output of an oscillator whose frequency is set equal to the carrier frequency (Figure 6). The mixer output signal includes the sum and difference frequencies (Figure 7).

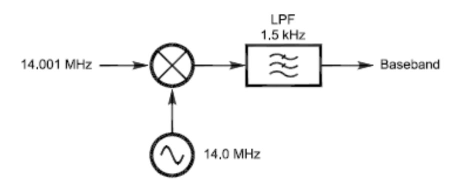


Figure 6. Synchronous Detection

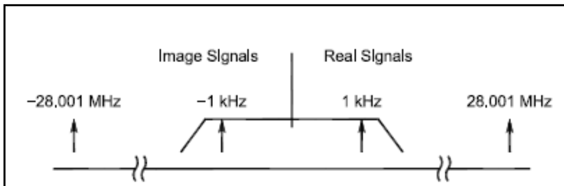


Figure 7. Mixer Output

In the technology described by Youngblood four voltage samples of the incoming carrier signal are taken during each period of the carrier. Differential amplifiers are used to produce I & Q signals which contain amplitude and phase information (Figures 9, 10).

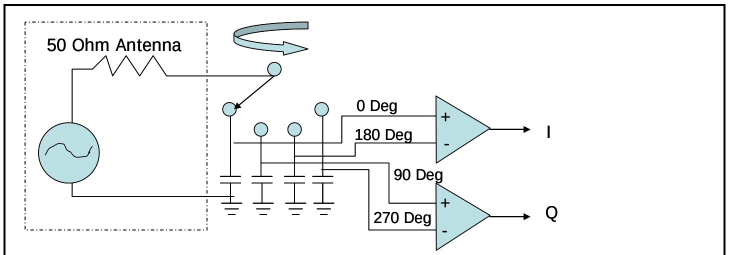


Figure 8. Synchronous Detection, I & Q Outputs

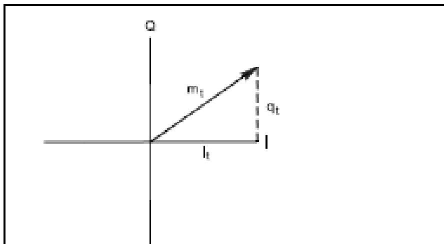


Figure 9. Magnitude & Phase

The I & Q signals are digitized by the stereo digital-to-analog converter circuits in a PC. Several free software programs are available that can be used to perform the process of transforming the signals to the frequency domain, filtering, and producing an audio signal. The students experimented with two of these including PowerSDR from Flex-Radio Systems. The example PowerSDR screen in Figure 10 shows that in this particular case many signals were available to be heard. The green band in the center of the PowerSDR screen is a bandpass filter whose frequency edges were set to select a signal-of-interest.

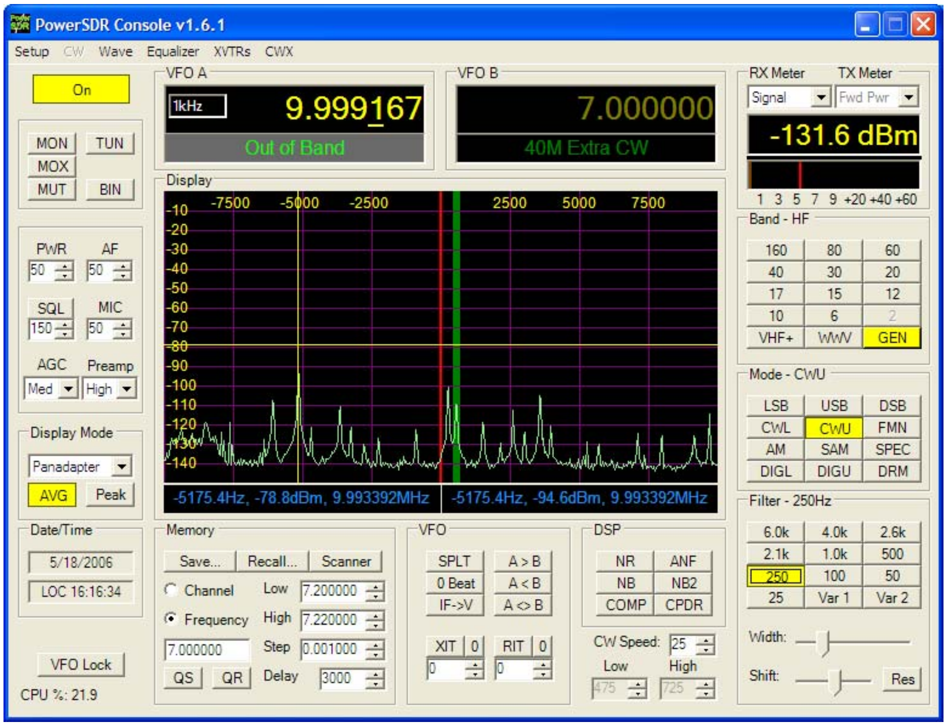


Figure 10. PowerSDR

Experiment Results

Recently the synchronous detection and I & Q circuits have become available in low-cost kits. Several 40-meter kits SoftRock SR6.2Lite were purchased from Tony Parks[8,9]. The circuit schematic and board layout are shown in Figures 11 and 12..

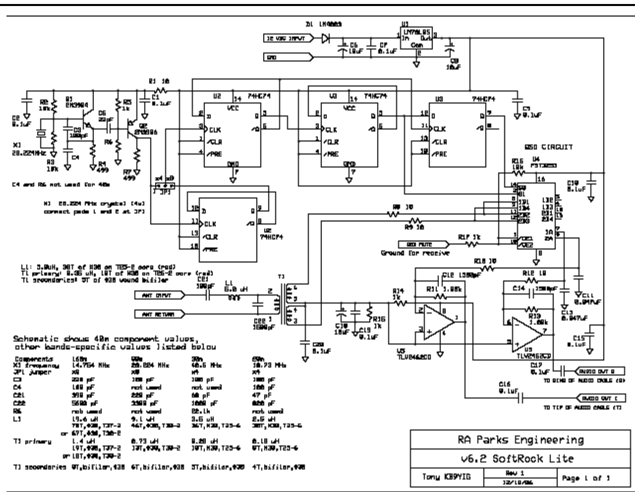


Figure 11. SRv6.2 Schematic

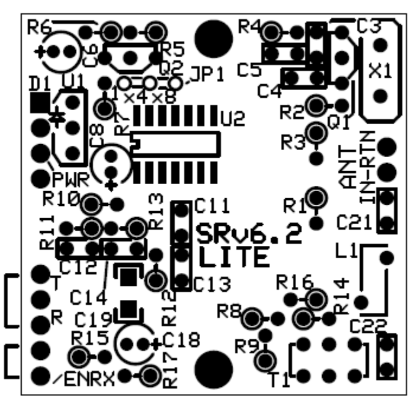


Figure 12. SRv6.2 Layout

The students assembled the boards (Figure 13) in a few hours. The assembly involved soldering a few surface-mount chips, but the relatively large pads were not difficult to solder. Some of the students are shown testing the circuit in Figure 14. The students also built hardware for mounting and connecting to two 40-meter amateur radio vertical antennas. The I &Q outputs of the 6.2 kit were connected to the stereo input jack in a desktop PC computer.

Figure 13. SRv6.2

Figure 14. Students Testing SRv6.2

As part of the testing process a 7MHz carrier modulated by a 1 kHz tone was input to the antenna connections on the SR6.2 board. Unfortunately no signals were observed using either of the software tools. This could have been caused by assembly errors or unfamiliarity with the software tools.

An earlier version of the kit that had been assembled and tested by an amateur radio friend was used to compare results. The two kits are very similar (Figure 15). Signals from an antenna at the author's home were input to the board. Signal display and audio were produced that were similar to described in articles and in downloads from the FlexRadio Systems website. A next step would have been to test the kit using the 40-meter antennas at the school, but time ran out. The semester ended so that will be a future project.

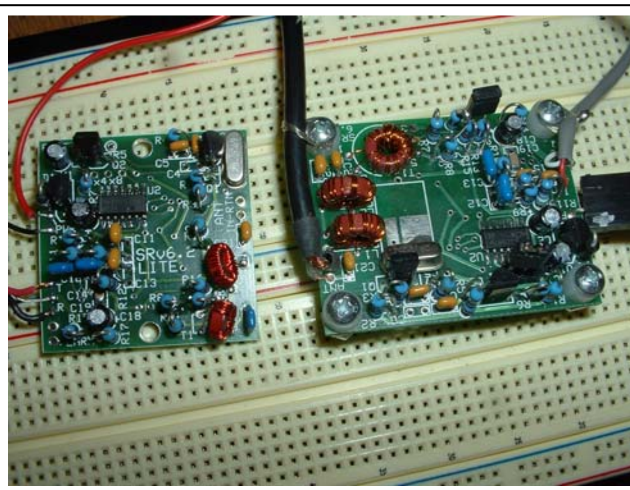
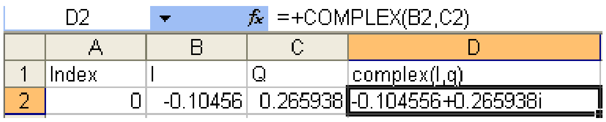


Figure 15. SRv6.2 and Earlier Version

Fourier Transform Studies

As part of this laboratory students reviewed the Fourier series and the frequency spectrum produced by a square wave on a spectrum analyzer. The students were introduced to the Fourier Transform, Fast Fourier Transform and digital filtering. In the future this work may include using spreadsheets to investigate applying windows to the I Q data, transforming to the frequency domain, and digital filtering. Phil Harman[10] recently presented Excel spreadsheets that included the following DSP processes:

Convert the data to complex form,



D2 fx =+COMPLEX(B2,C2)

	A	B	C	D
1	Index	I	Q	complex(I,q)
2	0	-0.10456	0.265938	-0.104556+0.265938i

Create a window to apply to the I & Q data (Figure 16) such Hanning from Julius von Hann.

fx =0.5*(1 - COS(2*PI()*A4/4095))

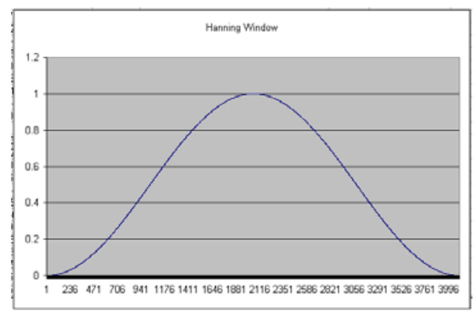
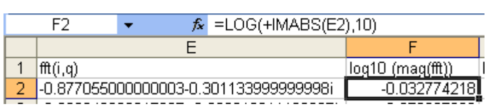


Figure 16. Windowed I & Q Data

Apply Fourier Transform, convert to magnitude and plot the results.



F2 fx =LOG(+IMABS(E2),10)

	E	F
1	fft(i,q)	log10 (mag(fft))
2	-0.877055000000003-0.301133999999998i	-0.032774218

The work with the Fourier Transform supports the ABET Program Criteria for EET & CET Programs. The criteria description includes, “In addition to the outcomes expected of associate degree graduates, graduates of baccalaureate degree programs must demonstrate…the ability to utilize statistics/probability, transform methods, discrete mathematics, or applied differential equations…”.

Conclusion

The DSP Experiment seems to be a useful addition to the experiments used in the digital communications course. Students were very interested in learning about digital signal processing and its use in amateur radio equipment. Students enjoyed building and testing the detector kits. Areas to examine include deciding how much effort to spend on transforms and assessing what students are learning.

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