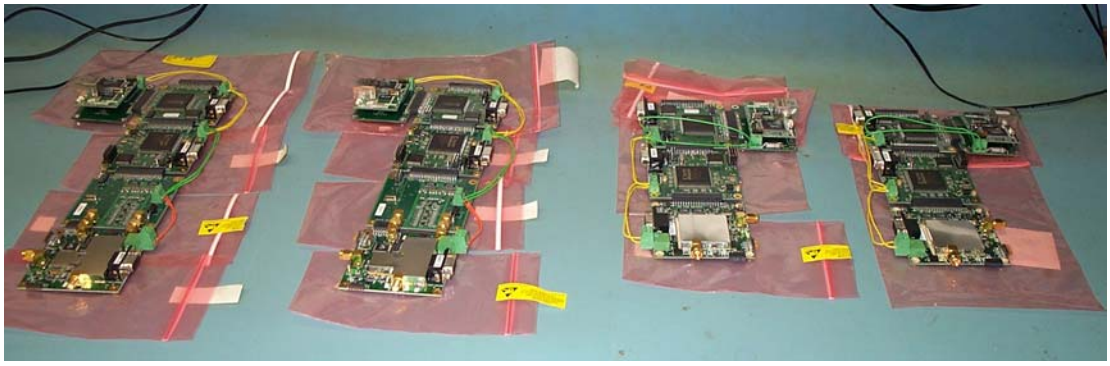
Summer Research Final Report

Wireless Communications



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Summary

Communication over a “wireless” network, though still being explored and developed, has lead to many new ideas about its uses in today’s world. The research being conducted during the summer of 2005 here at Stevens Institute of Technology aims to expand the capabilities of the wireless network which exists on the campus. The goal of the project was to develop a wireless testbed which would communicate and be received by dual-antenna transmitters and receivers, respectively, which would be placed around the campus. Eventually, the network of these communication blocks would be made up of ten nodes and the feasibility of this kind of network would be put to the test.

Through the use of ComBlocks supplied by MSS/ComBlock, the help of Professor Uf Tureli, and funding through the US Military the research hoped to make strides in this continuing field of study. Also aiding in the development in this project were several people on the WinSec (Wireless Network Security) research team at Stevens Institute of Technology. Their knowledge of the ComBlock system helped to further our understanding of how to better develop the testbed that would aid in the future research to be completed at Stevens.

Introduction

The summer research being continued the summer at Stevens Institute of Technology was that involving a wireless project that was said to be cutting edge and would have many applications in the field of engineering. Along with Shamim Akhtar, another Stevens student already working on the project, the research was conducted in the Wireless Research Lab in the Burchard Building. Professor Uf Tureli was the advisor for this project which was being continued from many previous semesters of development through senior design projects completed at Stevens. The hope for the new wireless testbed would be redesigning the current testbed which one would expect to improve the capabilities of previous testbed. With the help of the MSS/ComBlock which both supplied the ComBlocks and aided our development with them, we learned how to troubleshoot, program and expand the current setup to utilize a dual-antenna system.

ComBlocks are meant to improve upon and replace traditional simulation software so that testing can go far beyond the capabilities of one computer. ComBlock offers a real-time cost-effective alternative. [1] This research aims to build upon current knowledge about these ComBlocks and to expand them into a network which will hopefully be fully operational within the next year. Many sources were researched to find replacements for the ComBlocks, but fabricated communications boards are not readily available and the ComBlocks remained the ideal test equipment for the continuation of the research.

The ComBlocks are provided with proprietary software (ComBlock Console) which allows the alteration of the registers, which control how the ComBlocks operate. It is with this ability to change the settings of the ComBlocks with ease that make the ComBlocks themselves easy to learn how to use and more appealing for research purposes. Also, since ComBlocks can be programmed in two different ways, changing settings from a remote location becomes possible.

Matlab and Visual C++ code supplied by the people at WinSec enable the user to see a graphical representation of the spectrum being utilized. It is with these sets of code that the ComBlocks may be expanded for the continuing research and applied to other uses in the future. The code is meant to “see” the spectrum as the ComBlocks do and be able distinguish which frequencies (or channels) may be available. This form of data collection has potential for eventually reallocating those frequencies for specific purposes. Alterations to the source files provided by WinSec are limited to the changing of carrier frequencies and sample rate. This is the non-proprietary software. The research would require much time spent understanding the code provided and the code already available to ensure the efficient collection of data once the testbed is fully functional. Once operational, the testbed should prove useful for future applications in any field and would provide a more efficient network.

The dual-antenna system that needed to be created would need to be synchronized on both the transmitter and receiver ends of the testbed, and be efficient in data transmission. With the help of the technical staff at MSS/ComBlock and Professor Tureli, the research continued and progressed as far as was temporarily possible. The hardware and software are being improved upon to accommodate the new layout and will hope to be as efficient, if not more so, than it was previously.

Hardware

ComBlocks

ComBlock modules are small commercial off-the-shelf modules which are pre-programmed with essential communication processing functions, including modulation, demodulation, error correction encoding and decoding, digital to analog/RF, RF/analog to digital, formatting, data storage and baseband interface.[1] The research being conducted utilizes the ComBlocks for the digital to analog/RF and, conversely, the RF/analog to digital data transmissions. The ComBlocks are ideal for our spectrum analysis purposes because they are capable of data sampling at rates up to 40Msamples/sec and operating either in the 900MHz range or the 2.4GHz range for short or long range applications. The more samples we are able to collect, the more we can focus on particular sections of the spectrum we are analyzing.

The units are designed to be simple and easily configured to fit into any pre-fabricated cases. The individual ComBlocks each measure three inches square so they take up relatively less room than a typical breadboard. Setup of the units requires only 5 volts, a serial connection to set the initial programming of the registers, and a network cable attached to a LAN. The diagrams that follow show the initial setup of the ComBlocks and the possible configurations of the units.

Figure 1: Connecting power to the ComBlock [1]

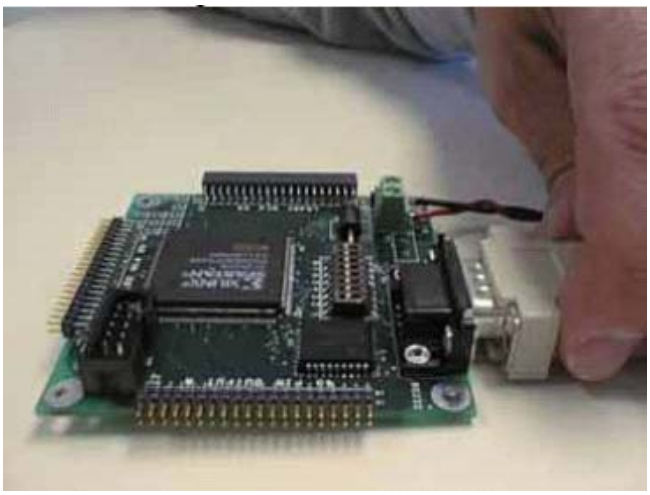


Figure 2: Connecting a Serial Cable to the ComBlock for initial programming [1]

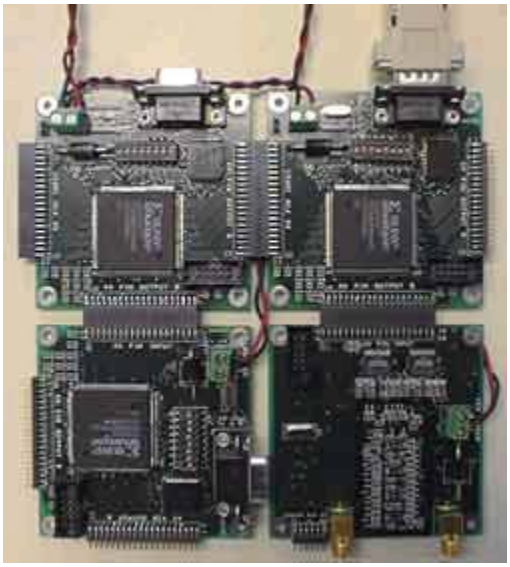


Figure 3: One possible configuration of the ComBlocks [1]

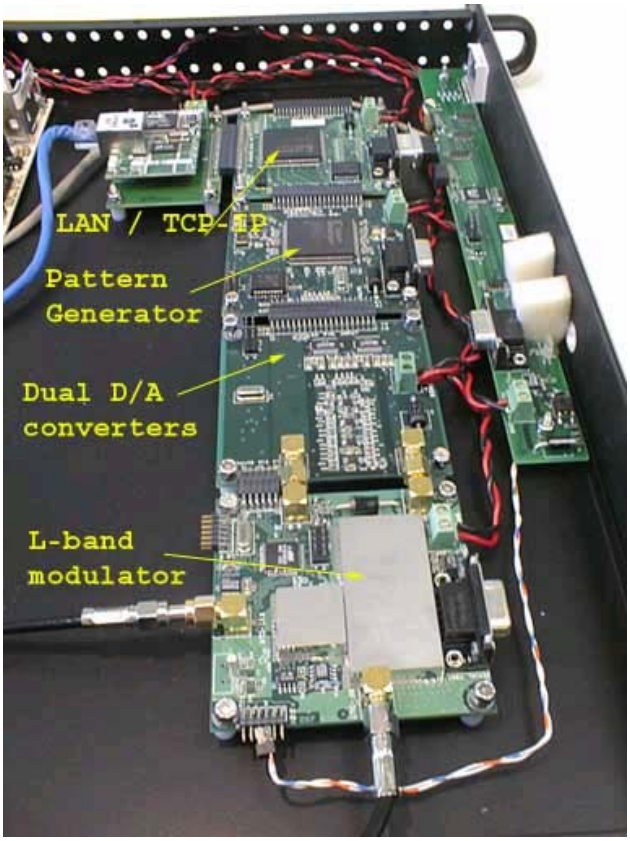


Figure 4: Configuration used for the actual testbed [1]

Once assembled and powered up, the ComBlocks are ready to be programmed. Most of the programming involves assigning a static IP address to the assembly which only needs to be completed once. By programming one of the units in the assembly, all of the units “understand” the general settings and can adjust themselves accordingly. The units only have to be powered off and turned back on once after being programmed in order for all of the new settings to take place. When connected to a network via LAN cable, the settings for the registers can also be changed and will update automatically without having to be turned off and on again.

The specific ComBlock modules that are used for the testbed are as follows:

Transmitter:

- **COM-5001 LAN/IP Network Interface**
  - Network IP is configured through this module. Another setting concerned with this project includes setting the trigger for each assembly to either internal or external. For this project, one of the assemblies will be set for an internal clock signal and all of the other units will be set to external triggers with respect to the internal trigger.
- **COM-8001 Arbitrary Waveform Generator**
  - Collects samples after user sets sample rates and memory segmentation configuration. Can download samples at rates of 0 to 40Msamples/sec. [1b]
- **COM-2001 Dual D/A Conversion**
  - Converts the complex baseband digital signal to two analog baseband signals.[1c]
- **COM-4001 Dual Band RF Modulation**
  - Dual-band [902-928 MHz] or [2.025 – 2.5GHz], quadrature modulator. Software selectable. Designed for use in unlicensed bands. [1d]

Receiver:

- **COM-5001 LAN/IP Network Interface**
- **COM-8002 Arbitrary Waveform Generator**
  - Acts as a data logger, analyzer, and an RF signature capturing device. [1e]
- **COM-3001 Dual-Band 915MHz / 2.4GHz Receiver**
  - Dual-band, [902-928 MHz] and [2.025 – 2.5 GHz] receiver, software selectable. Designed for use in unlicensed bands and satellite digital audio radio service (SDARS). [1f]

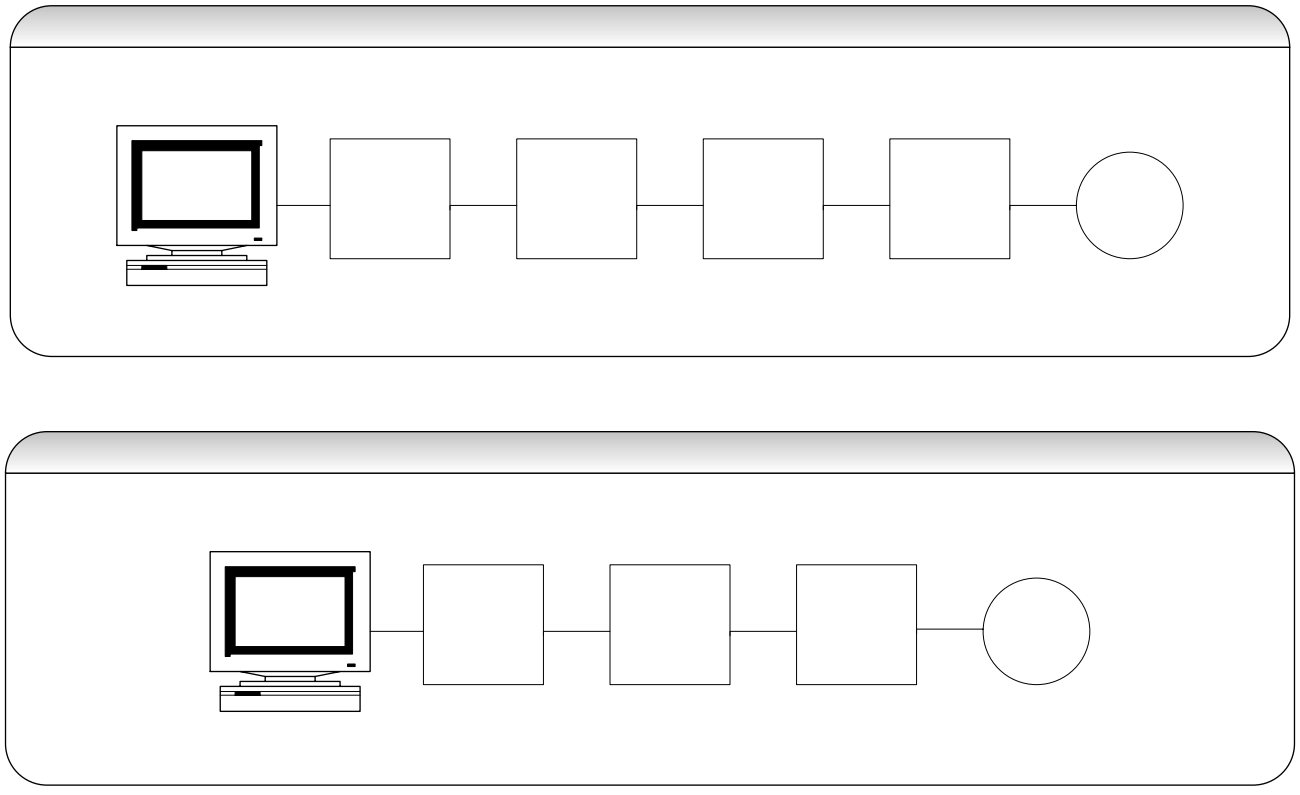


Figure 5: Block Diagram of the actual ComBlock configuration

Software

ComBlock Console (ComBlock Control Center)

The ComBlock modules are provided with a user interface called ComBlock Console which is used to set the registers as well as check the connectivity of the units of the assembly. This software is installed on any computer using a Windows operating system and will only communicate successfully with the ComBlocks if they are turned on. Once connected to the ComBlocks via serial cable to the computer, all of the registers for each of the individual modules can be set from a single serial connection. After the initial configuration, the assemblies can now communicate to any workstation that has the ComBlock console via LAN connection.

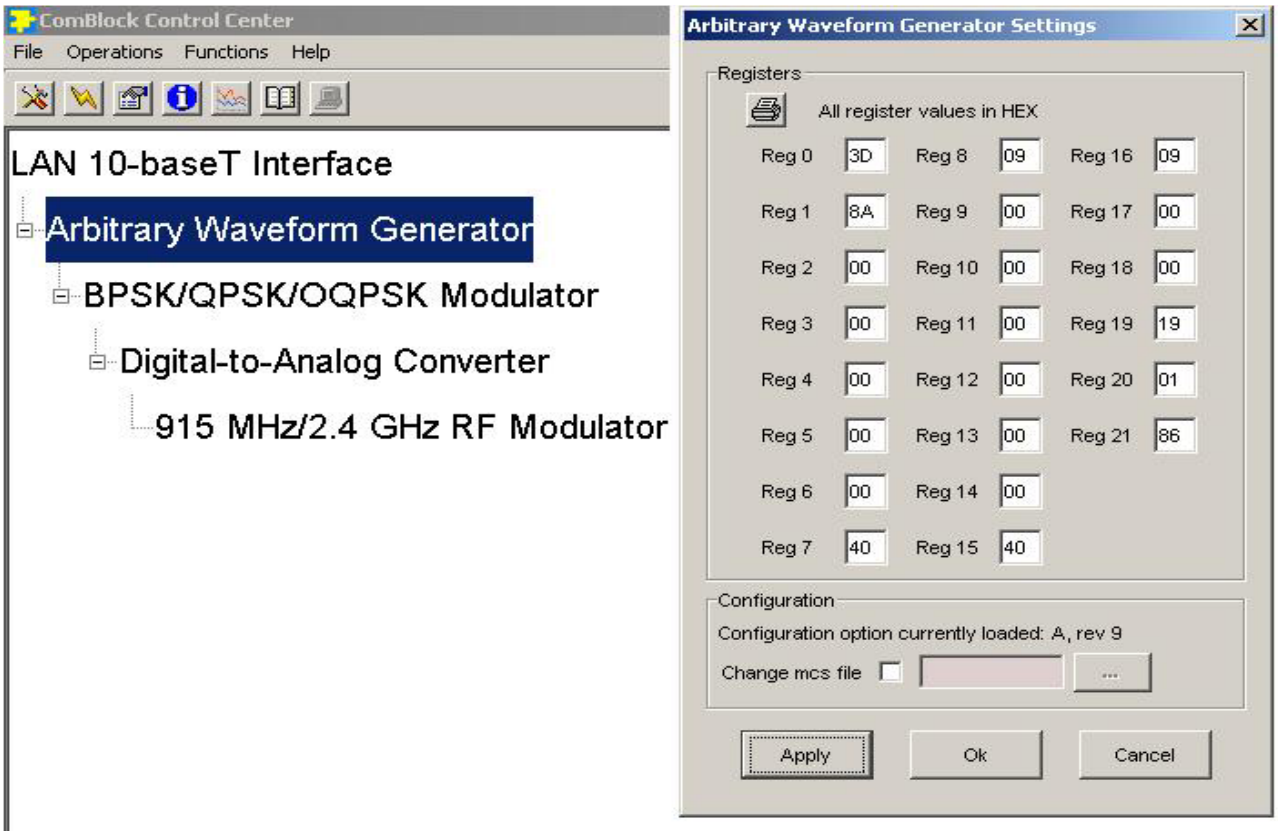


Figure 6: ComBlock Console

Matlab

The people at WinSec provided some code that had been previously written for the ComBlocks and explained its general function with respect to the research. The code running in Matlab would capture the data being received by the ComBlock receiver assembly and create a graph representing the spectrum seen at the RF end of the receiver. In theory, the receiver would pick up the used frequencies in the spectrum and display them in the Matlab graph. However, we were not able to see such a graph during the course of our research.

The first graph we received from the ComBlocks looked like this:

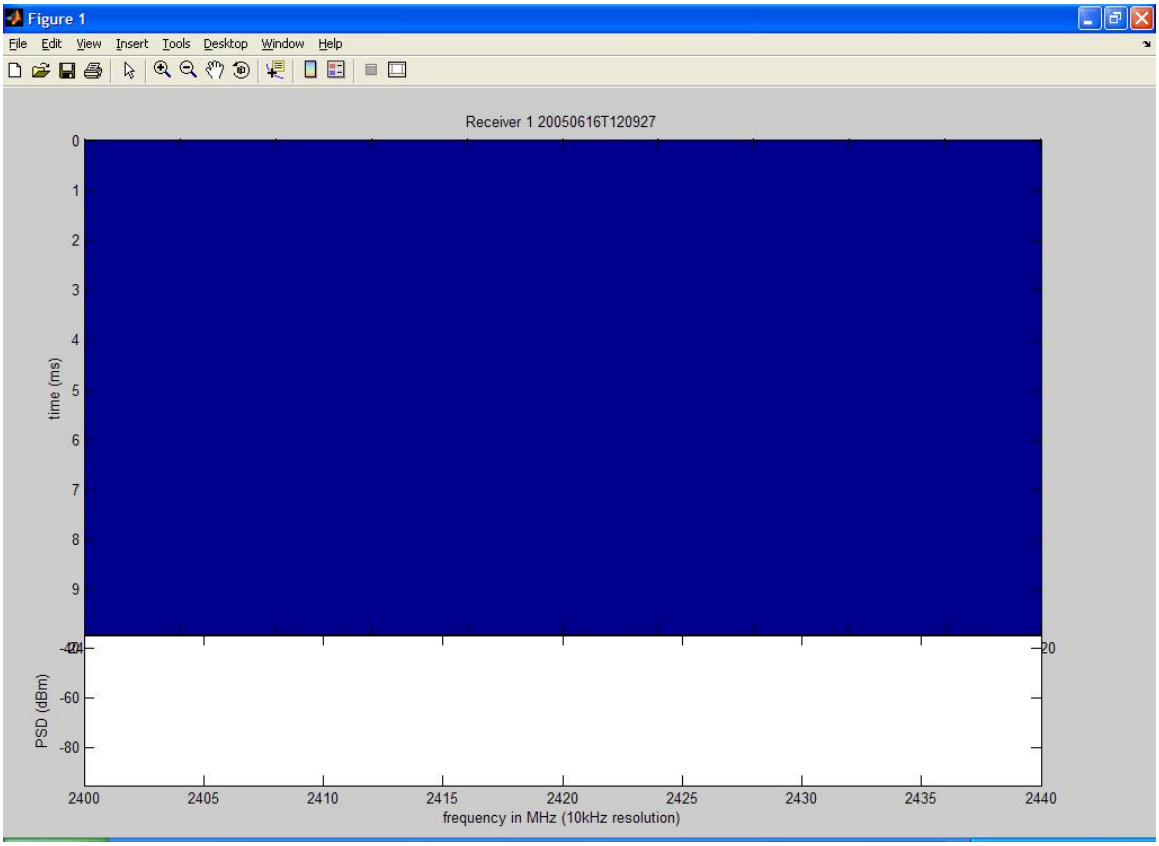


Figure 7: First graph from Matlab, no change in spectrum

With the help of another student Murat Bogaskesenli, who was studying Computer Science from a university in Turkey, we were able to identify some pieces of the code that was preventing what we thought was a signal being picked up in Matlab from the ComBlocks communicating. We began seeing lines on the figure that popped up in Matlab (Appendix B, pages 18-22) and thought they may have been something happening in the spectrum. As it turns out, these lines represented only carrier signals. However, we wouldn't find this out for another several weeks into the research.

As it turns out, the lines of code that we had been commenting out were essential elements in the data collection from the spectrum. The first modified line of code stopped the graph from refreshing every five seconds so that we could collect some data to analyze. Another line of code controlled the DC Offset and once it was commented out allowed us to see the carrier signals we had set in the code. We had not realized that we were not seeing anything in the spectrum. Continued analysis of this code is not necessary as the code was said to work as it was originally. Instead, the next step is to force a signal within the range of the specified spectrum should hope to show the occupied frequencies in the spectrum as well as the unused frequencies.

Visual C++

The Matlab code worked along side C code written for the ComBlocks. This code accounted for all of the programming elements required to make the Matlab code work correctly with the ComBlock modules and collect as accurate data as possible. Nothing was changed in the C code from the original version we received.

Design Ideas

The focus of the research this summer is to expand the original testbed to include two antennas at the transmitter and two antennas at the receiver, and for both sets of antennas to be fully synchronized. The testbed would include 10 such dual-antenna transmitter and dual-antenna receiver nodes set up around campus. The first thing that was explored was the feasibility of this approach using the ComBlocks. Initial talks with the people at MSS/ComBlock lead to the conclusion that ComBlocks may not be the ideal item for a testbed of this kind. Shamim began searching for alternatives to the ComBlocks that might serve the needs of the research testbed; however, he came up empty handed. The only other alternative was a PC Board that would be installed in a computer and might satisfy the needs of the project, but this was not a logical choice.

Later in the research, we began again to explore the possibilities of ComBlocks expanding and satisfying our needs. Two different designs were drawn up and priced for Professor Tureli to examine and determine a good candidate for the work. The first of the designs involved the two antennas branching from one IP connection and, in theory, being synchronized. The only issue with this setup was that the branching could only happen if one additional ComBlock module was purchased for its connectivity and not its function. If the module was not going to be useful, then the operation of the assembly might not have been very efficient in the end. The second design required two parallel assemblies of the transmitter and two parallel assemblies of the receiver synchronized by an external connection which did not seem feasible. After several talks with representatives at MSS/ComBlock, the idea for this setup became a possibility.

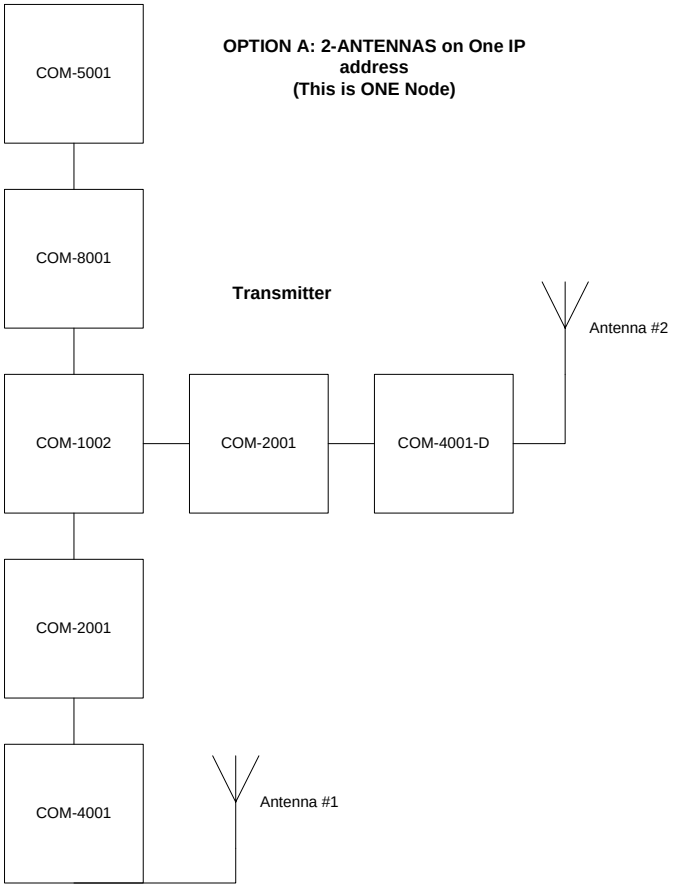


Figure 8: First Proposed ComBlock Layout

The design layout which Professor Tureli chose would prove to be no easy task. Ordering the ComBlocks was simple, but arranging the modules and synchronizing them could be a difficult task. One element of the synchronization which was not discussed was the need to synchronize the RF modules so that data is not lost, corrupted or duplicated between the dual-antenna assemblies. No instruction about this issue was provided from the representative from MSS/ComBlock, so only when the system is fully operational will this issue arise or be resolved.

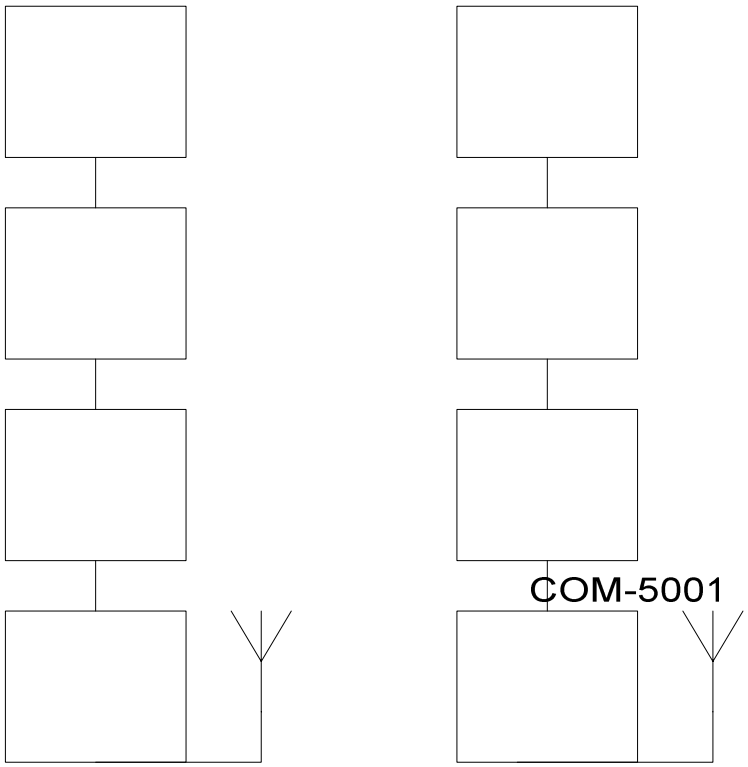


Figure 9: Parallel Transmitter Design

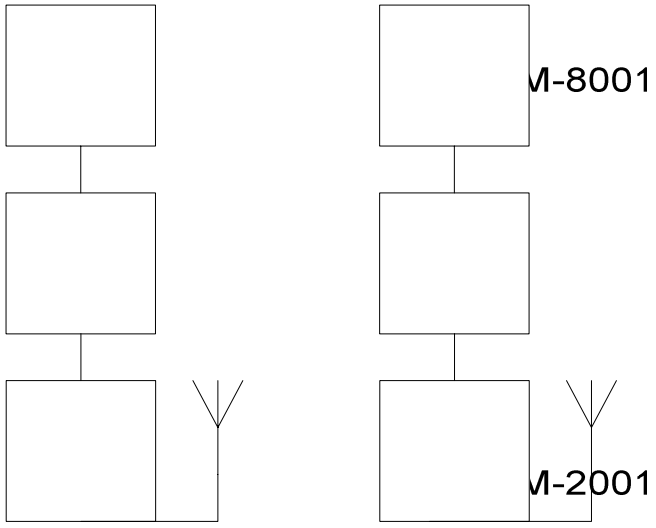


Figure 10: Parallel Receiver Design

The details of the communication received from the MSS/ComBlock representative regarding our proposed testbed design are as follows:

```
As per our last conversation, I think it is possible to synchronize all
four chains but it requires careful connection of a custom harness to
maintain the integrity of a 40 MHz clock signal and of the trigger signal.
For all comblocks to be synchronized,
(a) a common 40 MHz clock must be used in all four assemblies
(b) a common trigger must be used in all four assemblies.
This requires building special cables and maybe bending a pin or two at
a 40-pin connector.

I would advise to
(a) configure one of the two arbitrary waveform generator chains as
‘internal clock’, and all other comBlock assemblies as ‘external clock’.
Connect the 40 MHz clock from the first assembly to the left-most module
of the three other assemblies.
(b) use one COM-5001 to generate a trigger pulse by software command
over the LAN (see REG22 bit 1). The pulse is generated on pin
EXT_TRIGGER_OUT, pin B6 of connector J3.
Distribute this pulse to the other COM-8001 (EXT_TRIGGER_IN also pin
B6on J4) and the others COM-8002 (EXT_TRIGGER_IN pin A14 on J1).

Using the ComBlock Control Center, make sure that all arbitrary
waveform generators and all data acquisition are configured as ‘external
trigger’.
Then generate a pulse by controlling the COM-5001 REG22 bit 1 over the LAN.

That’s all.

The difficulty in all this is to make sure that all signals over the
cables are of good quality, without glitch. This requires extreme care
in building the harness cables.
```

Future Work

ComBlocks have much potential with the research at Stevens. Working alongside WinSec would continue to benefit the research because of their vast knowledge of the ComBlock system and its inner workings. The ComBlocks will need to be modified once the testbed is initially assembled according to the directions provided by MSS/ComBlock, but once operational, the expansion of these network nodes should be just the beginning of a new level of research. At this point, all that may be completed is the set up of the ComBlocks; however, the Matlab code may also need to be altered to accommodate the data that will be collected from the two antennas.

Conclusion

There is an ever growing need for wireless communications and versatility of a wireless network for adaptation into other applications. Stevens Institute of Technology continues its research year after year in order to fulfill this need for a more efficient network. The professors and students conducting work in the Wireless Research Laboratory in Burchard hope to find new ways to utilize the wireless network on campus and eventually around the world. With the help

of funding from the Department of Defense, the research continued this summer to the point of making great strides in the current achievements. The ComBlock testbed will continue to be an invaluable piece of test equipment as more efficient spectrum utilization becomes a new challenge in the near future.

To the students who continue the work, it would be best to review all of the documentation and try to get a grasp of the work that has been completed. There is much more work to be done on the testbed which can always become a potential senior design project.

References

[1] www.comblock.com:

a) **http://www.comblock.com/download/com5001.pdf**
b) **http://www.comblock.com/download/com8001.pdf**
c) **http://www.comblock.com/download/com2001.pdf**
d) **http://www.comblock.com/download/com4001.pdf**
e) **http://www.comblock.com/download/com8002.pdf**
f) **http://www.comblock.com/download/com3001.pdf**

[2] Senior Design Projects:

a) **http://koala.ece.stevens-tech.edu/sd/archive/02F-03S/websites/grp15/public_html/**
b) **http://panda.ece.stevens-tech.edu/sd/grp5/**

Appendix A: Testbed Photographs

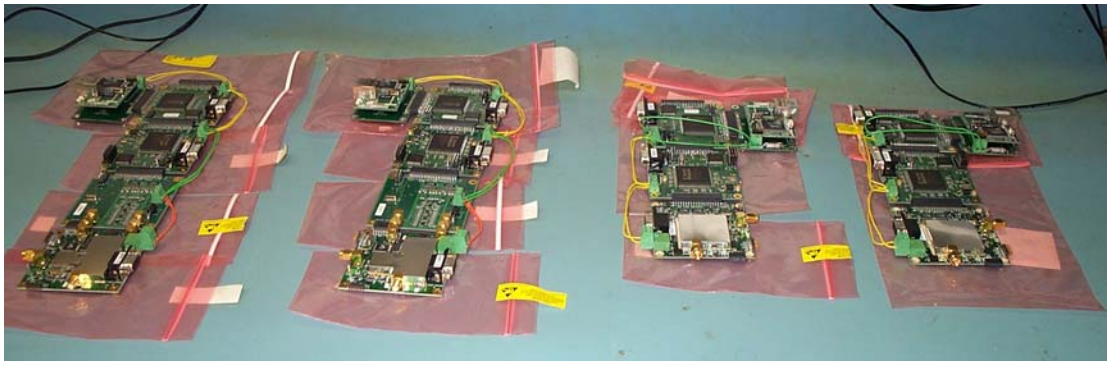


Figure 11: Transmitter assemblies (left) and Receiver assemblies (right)

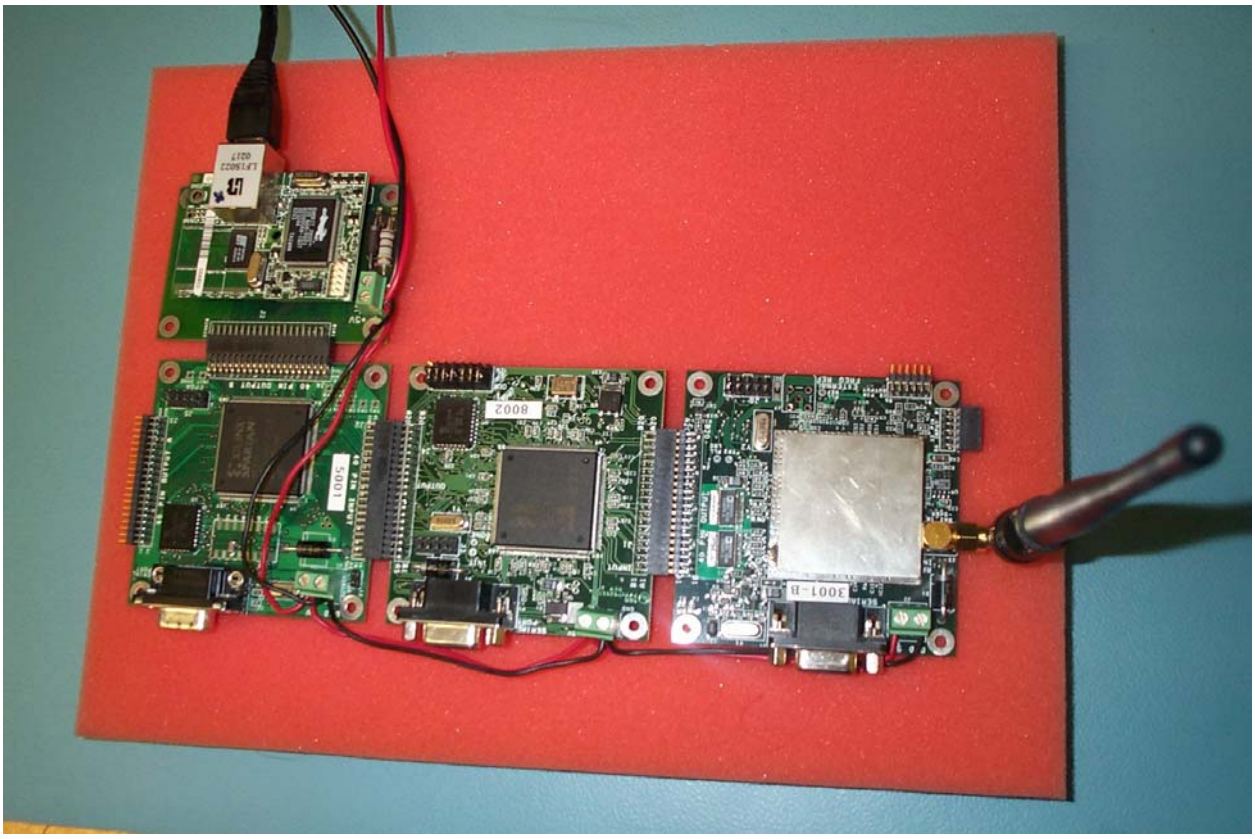


Figure 12: Receiver assembly connected to the LAN [2]

Appendix B: Weekly Reports

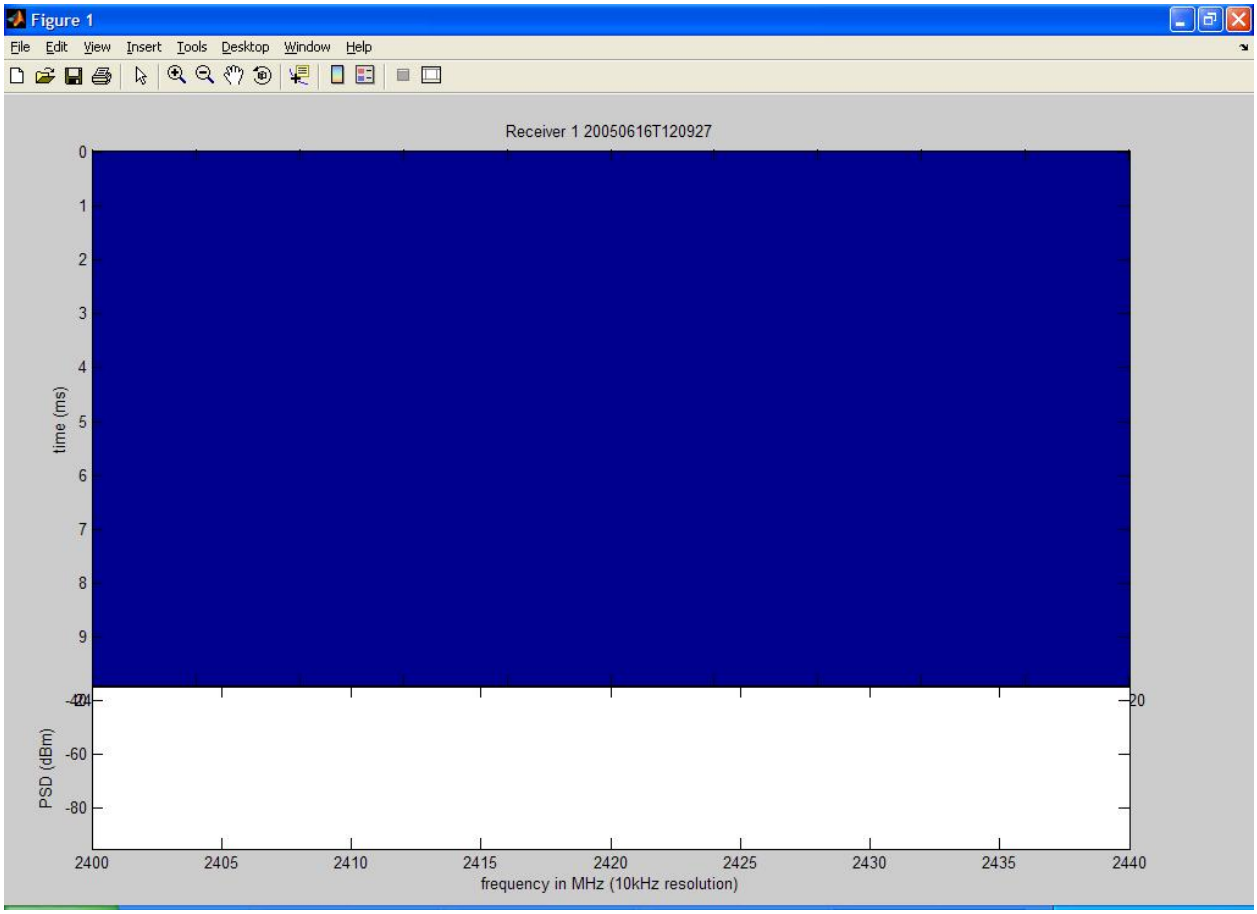
Week 1:

- Read all documentation and researched any available information pertaining to the ComBlock system.
- Checked all hardware because of an earlier finding that the receiver may not have been working.
- Once both TX and RX were functional, I tried to figure out the ComBlock GUI a Stevens person had developed, but didn't get very far.
- Attended a meeting with a representative from Picatinny to learn about the ways this research can be applied and got feedback about the goals we have set for the research this summer.
- Received and began analyzing Matlab Code designed for the ComBlock.

Week 2:

- Learned how to use GUI creator in Matlab 7.0.
- Continued analyzing the Matlab code provided by Theodore on Tuesday.
- Worked on ComBlocks to ensure they were fully functional.
- Connected to ComBlocks and started receiving data representing the spectrum.
- Attempted to modify Matlab code to be able look closer at the data being received.

Graph of Receiver Spectrum [Fig 1]



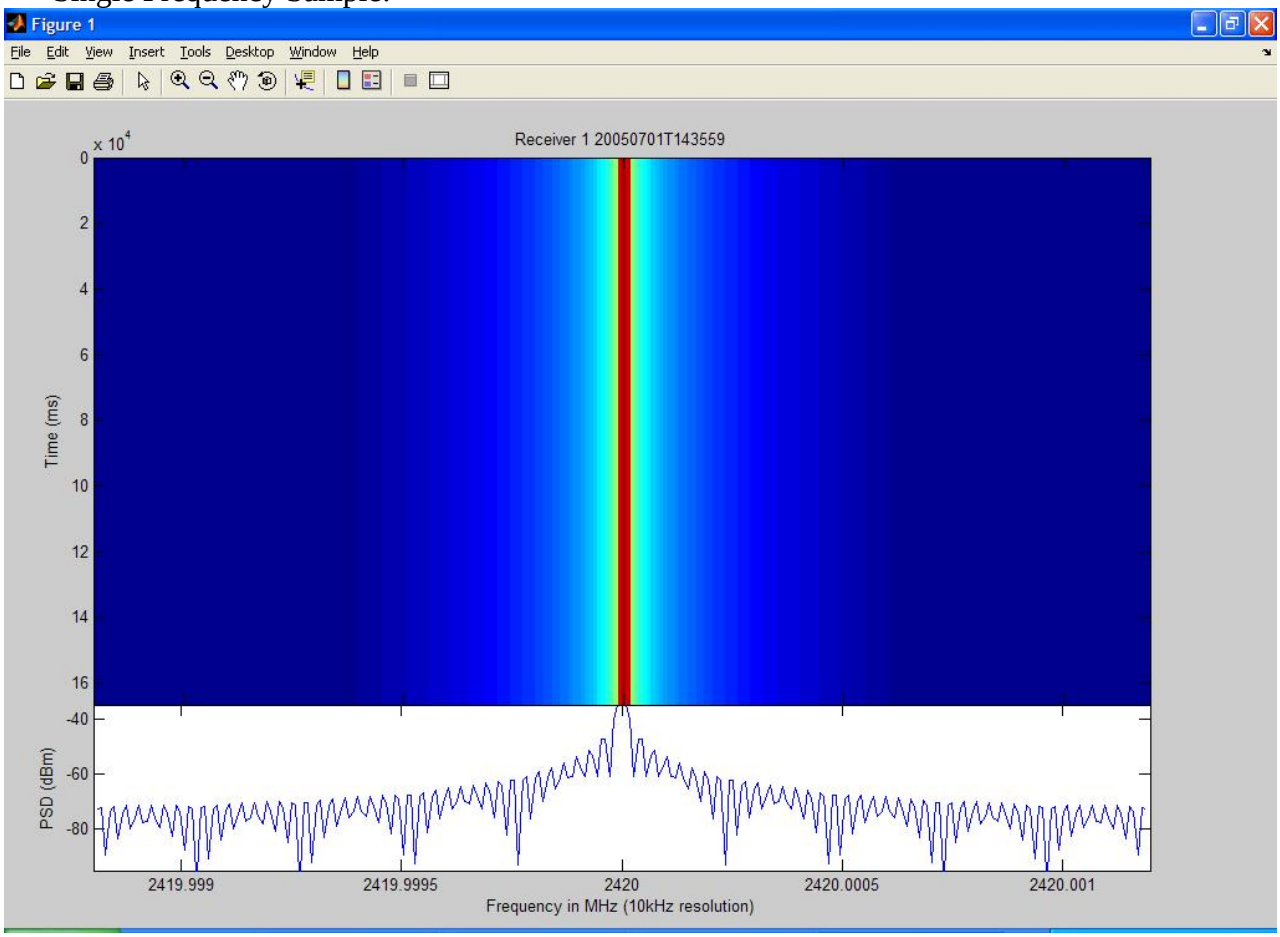
Week 3:

- Analyzed Matlab code to determine source of sampling rate and refresh rate of the plot.

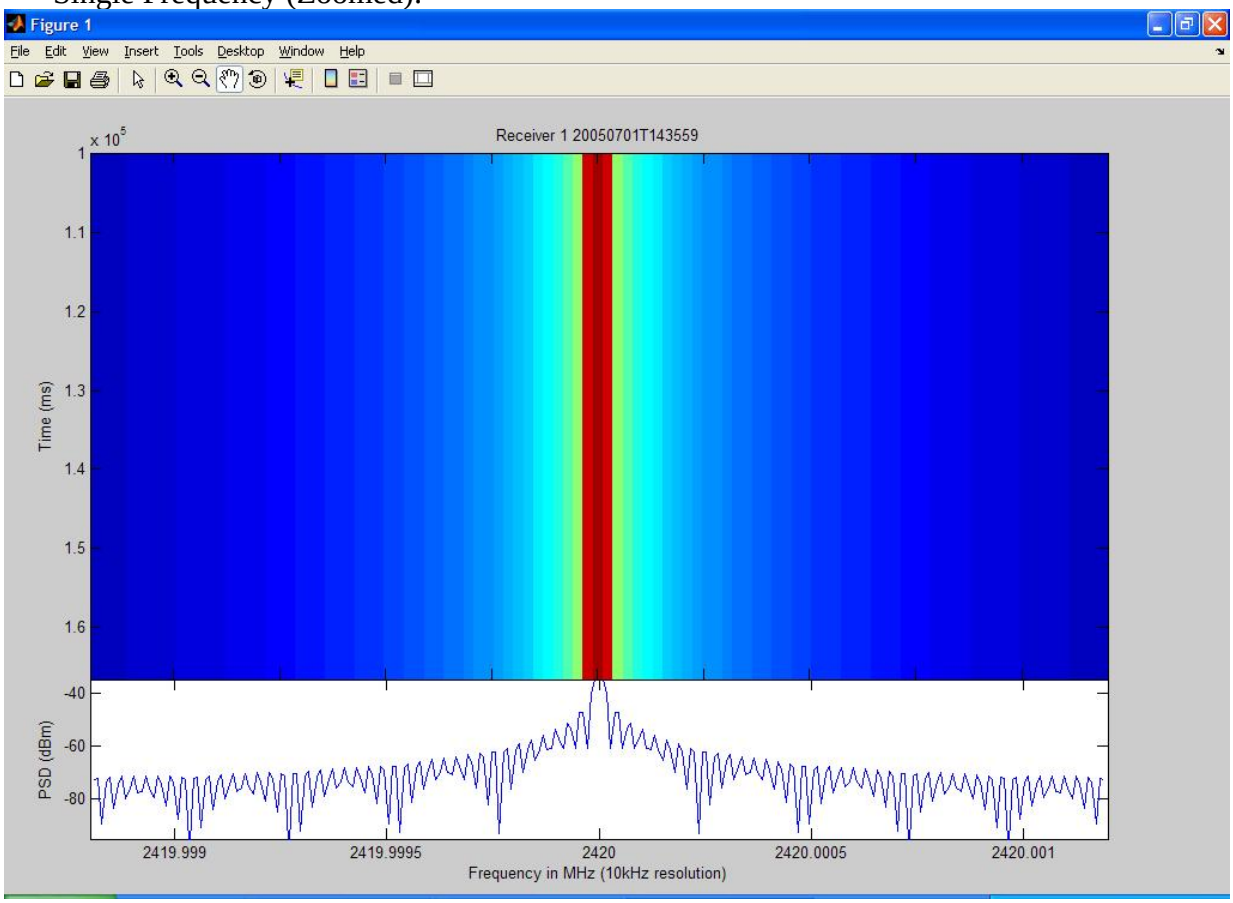
- Tested ComBlock setup without Modulator and Demodulator PCBoards and found no change to functionality.
- Verified registers for internal/external clock settings in the Transmitter and Receiver.
- Provided assistance in the requisition of ESD protection devices.
- Read available documentation from previous Senior Design projects involving the ComBlocks.
    - **http://koala.ece.stevens-tech.edu/sd/archive/02F-03S/websites/grp15/public_html/**
    - **http://panda.ece.stevens-tech.edu/sd/grp5/**
- Reread datasheets for the ComBlock setup:
    - **COM-5001 LAN/IP Network Interface**
    - **COM-8001 Arbitrary Waveform Generator**
    - **COM-1002 BPSK/QPSK/OQPSK Modulator**
    - **COM-2001 Dual D/A Conversion**
    - **COM-4001 Dual Band RF Modulation**
    - **COM-1001 BPSK/QPSK/OQPSK Demodulator**
    - **COM-3001 Dual-Band 915MHz / 2.4GHz Receiver**

Week 4:

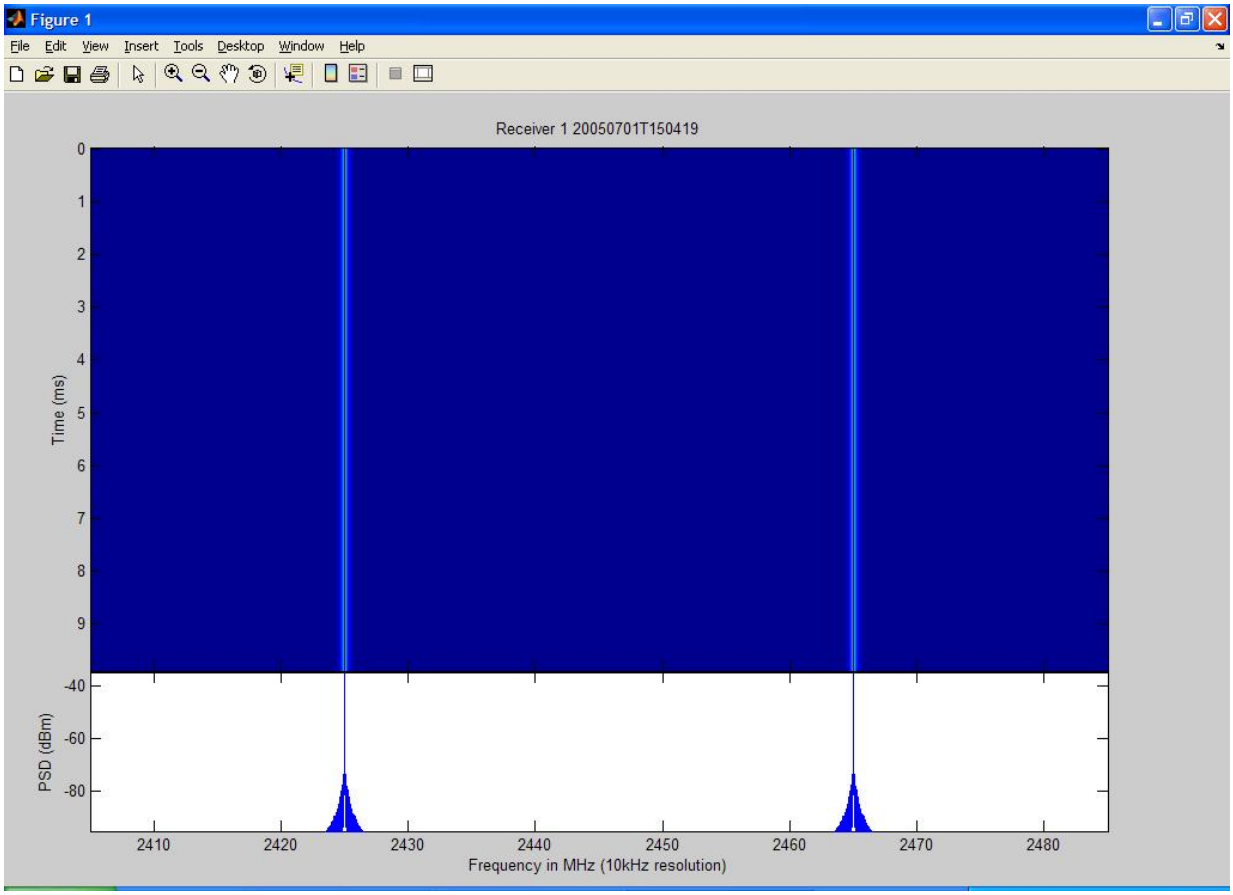
- With the help of Shamim and Murat, we successfully collected graphs from the Matlab code which were received by the ComBlocks:
- Single Frequency Sample:



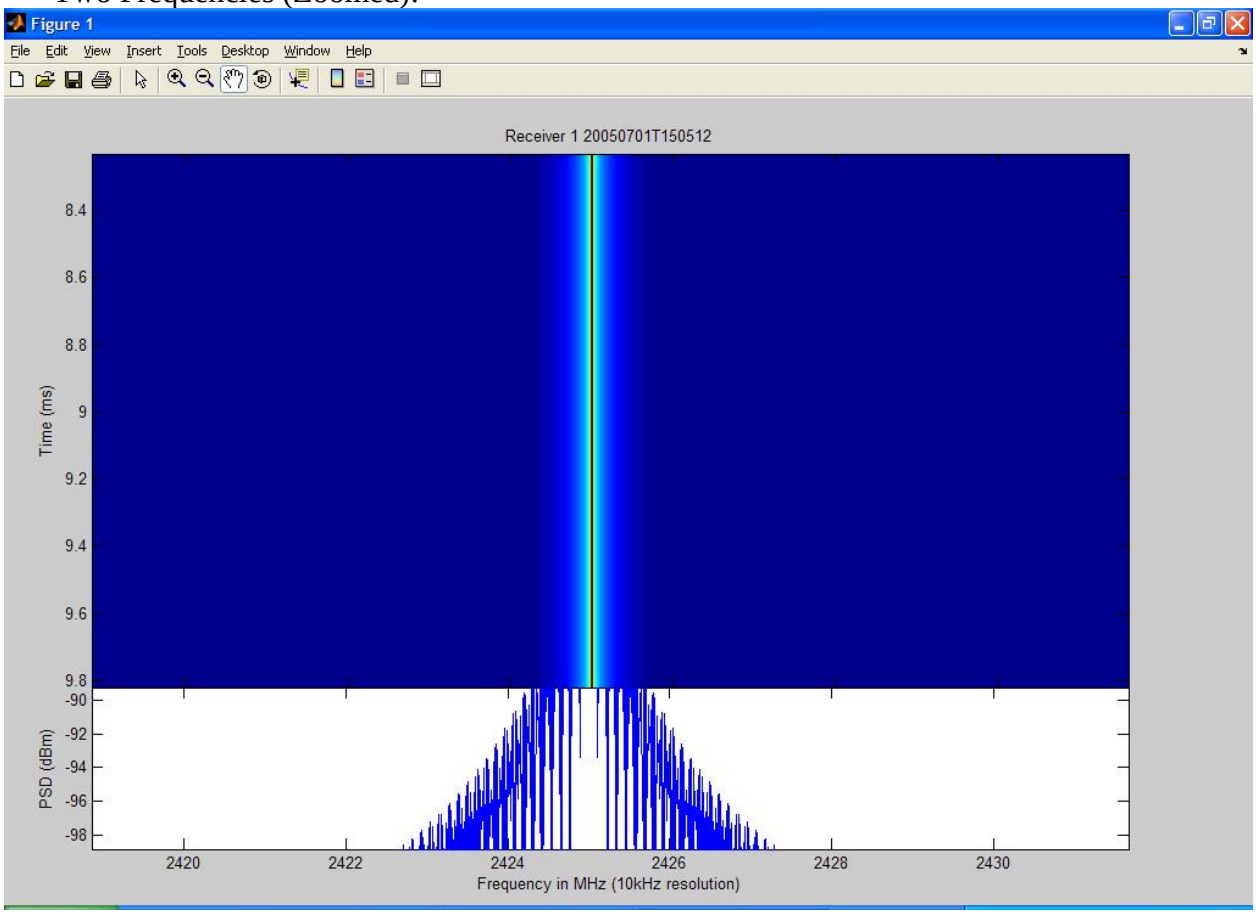
- Single Frequency (Zoomed):



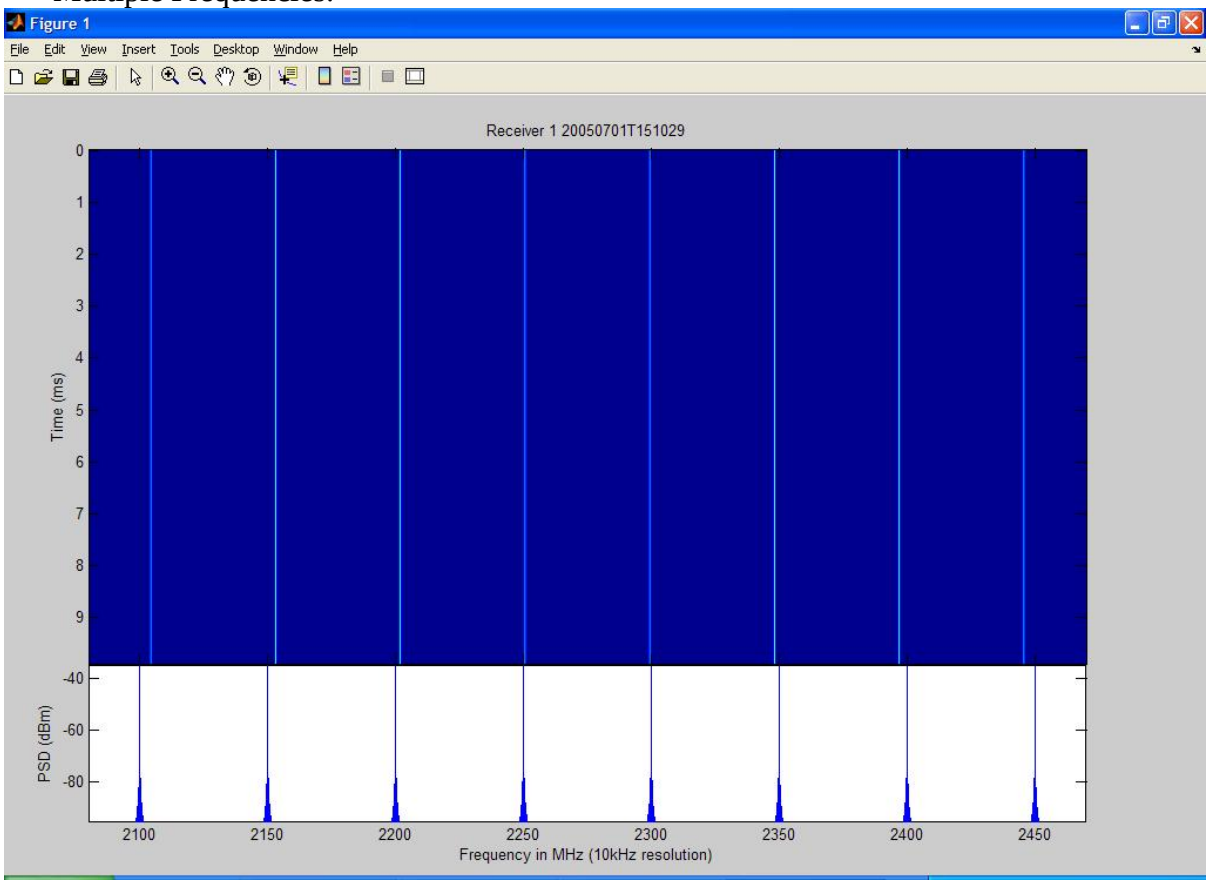
- Two Frequencies Sample:



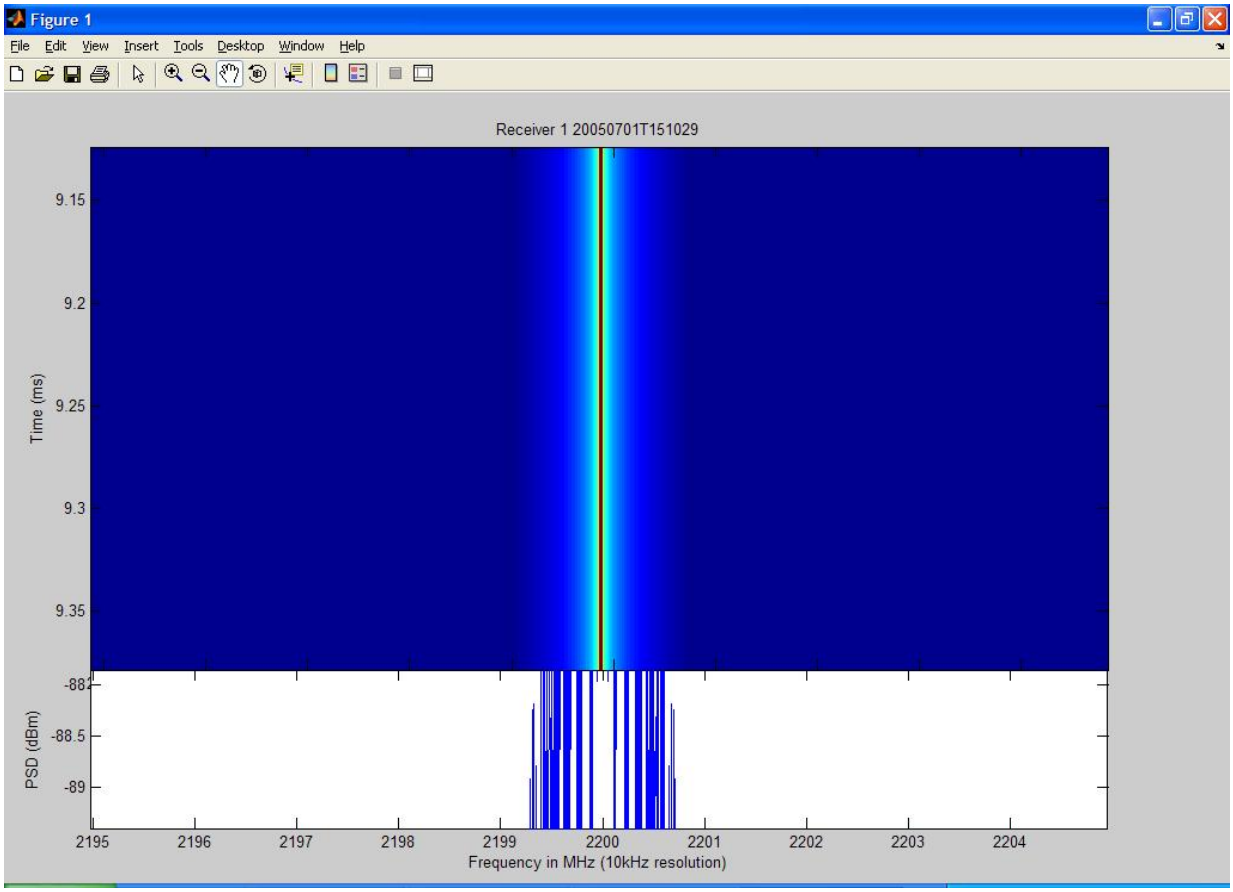
- Two Frequencies (Zoomed):



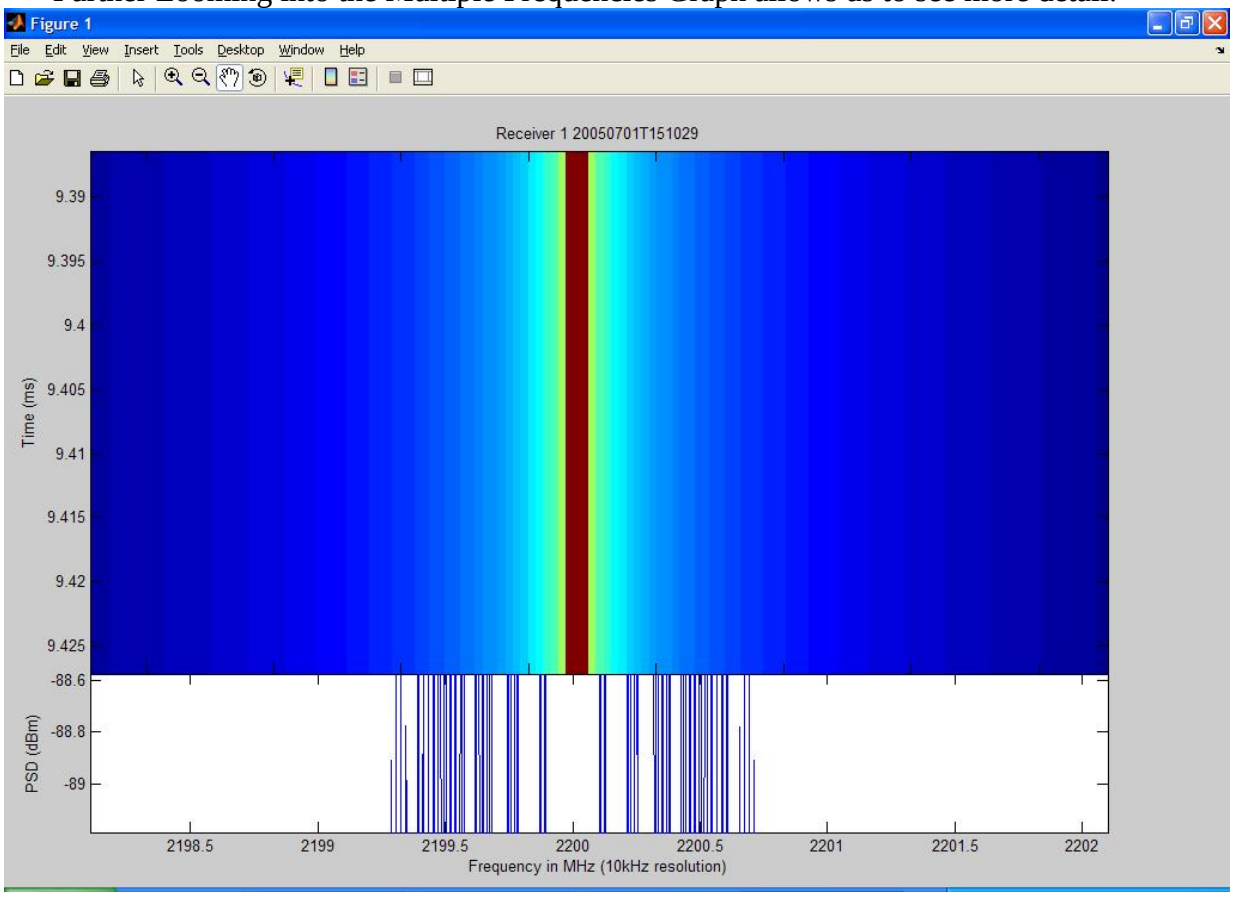
- Multiple Frequencies:

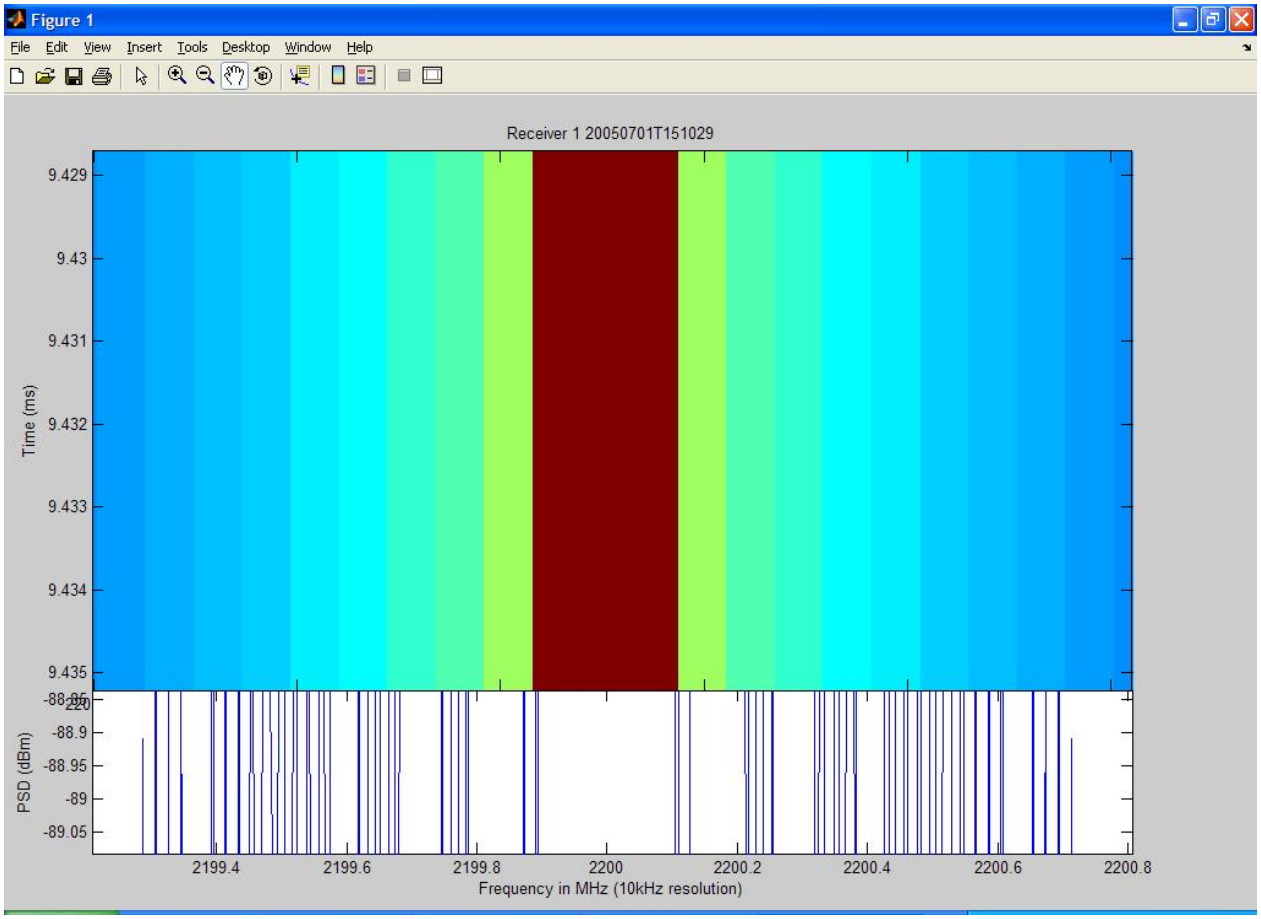


- Multiple Frequencies (Zoomed):

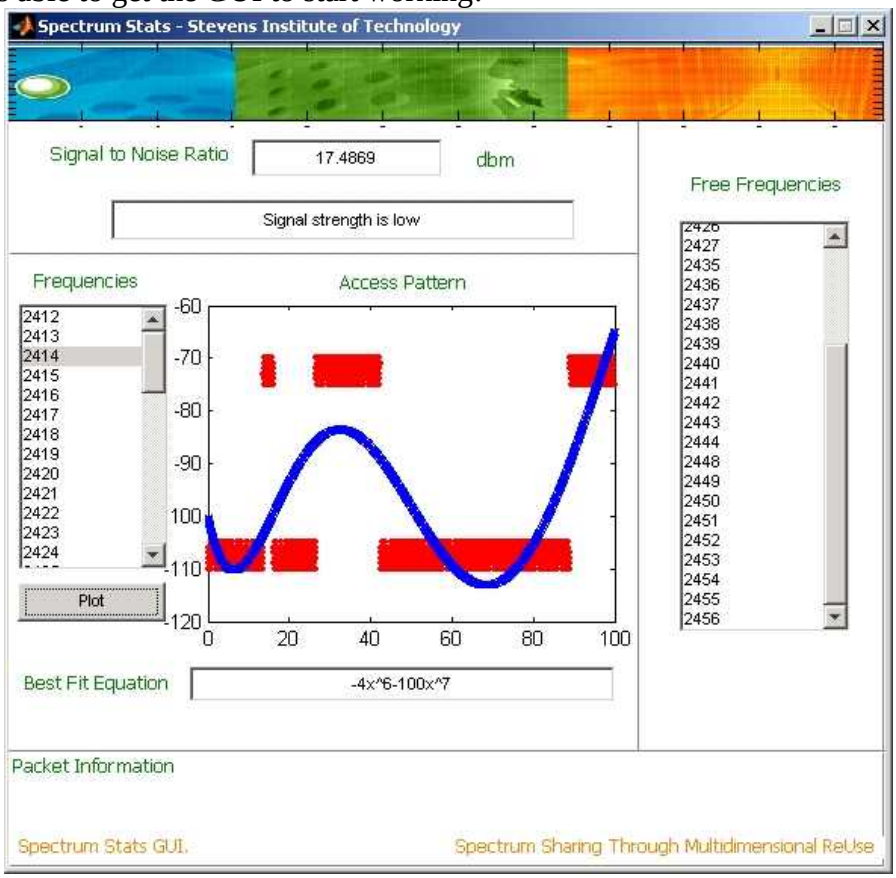


- Further Zooming into the Multiple Frequencies Graph allows us to see more detail:





- Murat was able to get the GUI to start working!

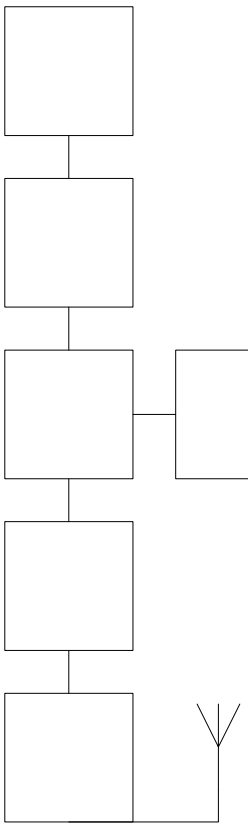


- Researching wireless communications at other universities and government websites.
  - Universities:
    - University of California: "High Speed Wireless/Wireline Data Communications" http://www.ucop.edu/research/micro/97_98/97_040.pdf
    - Berkley Wireless Research Center: http://bwrc.eecs.berkeley.edu/
      - "PicoRadio Supports Ad Hoc Ultra-Low Power Wireless Networking" http://bwrc.eecs.berkeley.edu/Background/IEEE%20Computer%20Magazine%20Article/r7042b.pdf
      - "A Service Based Universal Application Interface for Ad Hoc Wireless Sensor Networks" http://bwrc.eecs.berkeley.edu/Research/Pico_Radio/docs/SensorNetworksServicePlatformv1.pdf
- Government:
    - Wireless Ad Hoc Networks: http://w3.antd.nist.gov/wahn_home.shtml
- Other Sources:
    - Computer Magazine: http://www.computer.org/computer/homepage/0204/GEI/

Week 5:

- Spoke with Professor Tureli about next step for ComBlocks. Tureli decided that since the COM-1002 and COM-1001 boards are not necessary for this setup, that Option A is not a feasible option for the dual antennas he is looking for.
- Options B and C use two transmitter units in parallel and must be synchronized in order to work efficiently.
- We contacted ComBlock again to find out how we could connect the units together like Professor Tureli wanted. It seems possible; we just need to find out how.
- Temporarily borrowed TX/RX pair from Theo in order to continue testing. Ordered two new TX/RX pairs to begin testing with 2-antennas.

Option A:



OPTION A: 2-

COM-5001

(This

COM-8001

Transmitter

Options B and C:

Option B: 10 Tx/Rx Nodes consisting of 2 transmitters and 2 receivers COM-1002 COM-2001

Option C: 5 Tx/Rx Nodes consisting of 2 transmitters and 2 receivers

COM-2001

COM-4001

Antenna #1

2 Transmitters

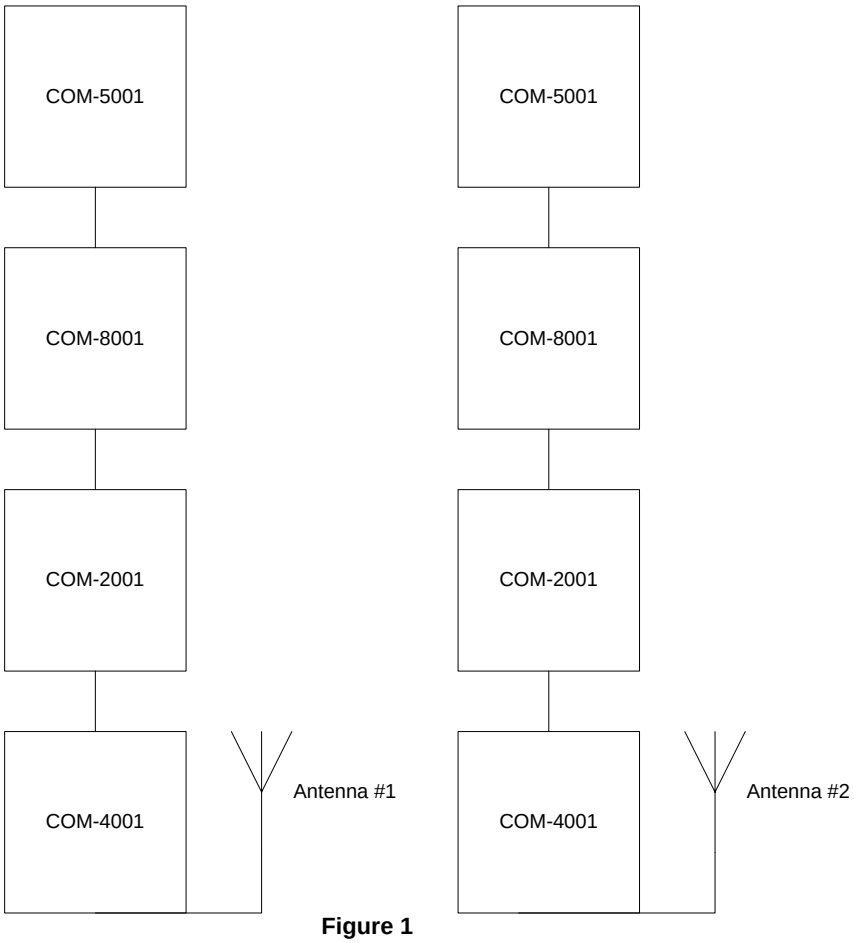


Figure 1

OUR GOAL:

To assemble 2 separate transmitters to transmit
data to a dual-antenna receiver (See Figure 2)
and not have repeated data sent or packets lost.

2 Receivers

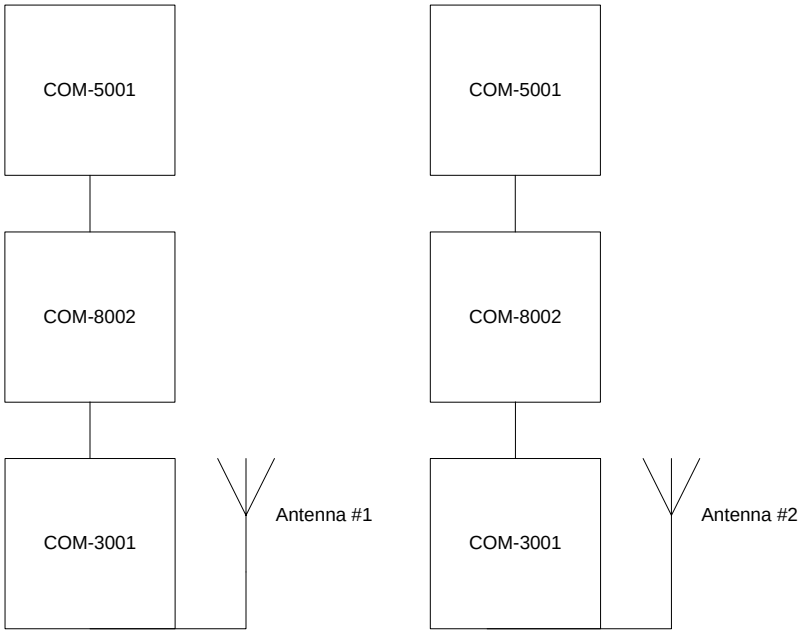


Figure 2

OUR GOAL:

To assemble 2 separate receivers so as to be connected to receive data from a dual-antenna transmitter (See Figure 1) and not have repeated data collected or packets lost.

Week 6:

- Learned how to install Linux 10.2 on several of the machines in the wireless lab.
- Helped install Matlab on Linux with necessary toolboxes.
- Spoke with ComBlock about the development of our setup and received feedback about our proposed plan of action.
- Worked on successfully connecting to borrowed ComBlock units.

Week 7:

- Attempted to connect to ComBlocks through serial cable. Could not find the problem.
- When a possible source of the problem was identified, we tried changing the network connection and the register settings.
- Gave presentation to gentlemen from Picatinny and learned about the upcoming applications for our research.

Week 8:

- Attempted to reformat and install Linux 10.2 on one of Professor Tureli's computers in the lab, but had major issues with it. The installation will hopefully be complete soon.
- Got ComBlocks in from MSS/Comblock on Friday.

- Set up ComBlocks in the lab to be assigned IP addresses. Had problems finding MAC addresses for the ComBlocks.
- Searched www.comblock.com for a clue as to finding the MAC address. Called ComBlock.
- Finished setting up the ComBlocks.

Week 9:

Week 10:

Week 11:

Week 12: