

Jayhawk Engineering Laboratory

Weather Satellite Imaging System

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Abstract

The National Oceanic and Atmospheric Administration (NOAA) has 4 satellites that orbit the earth and transmit live weather data that can be captured using an appropriate antenna and processing methods. The goal of this project is to develop a weather station capable of receiving and processing a satellite signal in order to produce an image to assist in observing weather conditions. To achieve this, the system in this project consists of a Quadrifilar Helix antenna (QFH), a pre-amplifier, a receiver and a PC sound card. The data output from the sound card is recorded as a wave (.wav) file. This wave file is decoded using processing techniques in the Matlab programming environment. This project provides a comprehensive report on antenna construction procedures and signal processing techniques used to achieve a complete readable weather image. There are numerous ways to achieve the results of this project and various design choices were made depending on a number of factors such as budget considerations and resource availability. The project was completed on time and met all the specifications in order to successfully capture a signal and process it.

1. Introduction and Background

1.1 Purpose

The purpose of this project is to implement a weather satellite station that can decode an APT (Automatic Picture Transmission) signal into an image. This project helps explain how a signal sent from a satellite can be tracked, amplified and processed. This processed signal will then output an image displaying the weather conditions and assist in forecasting. There are various ways to develop this system and the approach in this project is one way it can be achieved.

1.2 Background

There are three different types of weather satellites: low earth orbiters (LEO), medium earth orbiters (MEO) and geostationary orbiters (GEO). Low earth orbiting satellites range from a few hundreds to a thousand kilometers in altitude. Medium earth orbiting satellites orbit at about 10,000 km above the earth. On the other hand, geostationary orbiting satellites are at approximately 40,000 kilometers in altitude.

The GEO satellites move at the same speed as the earth's rotational speed and hence they appear to be suspended above one point. LEO satellites constantly move with respect to the earth's surface and are lower orbiting satellites so they tend to achieve sharper pictures. In this case, LEO satellites are used to receive the signal. This is mainly due to the better image quality and also due to the fact that LEO satellites orbit from pole to pole, implying that they are bound to pass over a particular region at least twice a day. Their orbits are 840 kilometers in altitude and they circle the planet once every 104 minutes. The US National Oceanographic and Atmospheric Administration (NOAA) have both GEO and LEO satellites.

Currently, there are 4 operational NOAA satellites that orbit and send signals: NOAA-15, NOAA-16, NOAA-17 and NOAA-18. The basic operation of the satellite uses cameras that scan the visible spectrum as well as the infrared spectrum and take strips of images that would span approximately 3000 km. This is done repeatedly to make a continuous image. This image is then transmitted at 137 MHz right away and not stored on the satellite. This signal can be received through the antenna while the satellite is overhead, which can last up to 15 minutes. The Quadri-filar Helix antenna (QFH) is regarded as one of the best omni-directional circularly polarized antennas that suits this system.

Although, the signal can be heard for up to 15 minutes, it tends to be noisy for the first and last minutes. The best signal to noise ratio can be achieved when the satellite pass is directly overhead the antenna. Once the signal arrives at the antenna it is amplified immediately using a pre-amplifier to achieve a better noise figure for the entire system. Once the signal is amplified it can be FM demodulated using a receiver operating at 137 MHz. The receiver demodulates the FM carrier and leaves an AM sub-carrier data signal that is processed to display an image. There are several receivers that meet this specification.

1.3 Features

This system is capable of automatically detecting when a satellite is overhead and capturing the signal immediately. Even though Nova, satellite-tracking software, was used to track the satellite during the course of the project in the interest of time efficiency, the receiver is equipped to continuously search and lock onto a signal every time a satellite passes within range. Once the receiver passes the signal through the sound card it can be processed to produce an image within a few minutes. The pre-amplifier used in this system has a gain of approximately 18 dB.

1.4 System Configuration

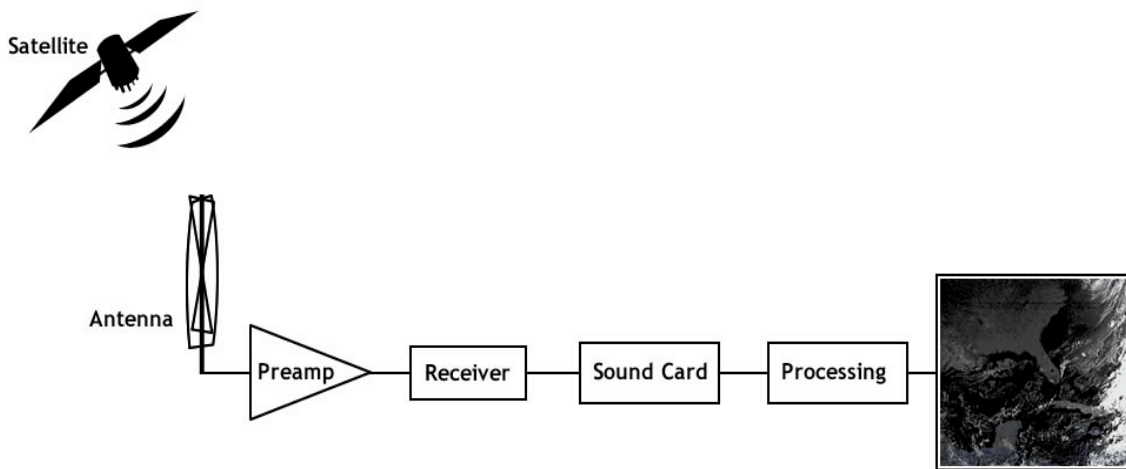


Figure 1: Hardware block diagram

The figure shown above demonstrates the basic system configuration of this project. The signal from the satellite is captured by a QFH antenna which is amplified by a Hamtronics pre-amplifier. The data is then retrieved from this signal using a receiver operating at 137 MHz. Once the signal passes through the receiver it is passed through a sound card which performs the analog to digital conversion of this signal. Using a computer sound card for this process proves to be more inexpensive compared to other analog to digital conversion methods. The signal from the sound card is recorded as a wave (.wav) file. This wave file is then decoded in Matlab to generate an image.

2. Installation

2.1. Components

- Antenna
- Tri-pod
- Pre-amp
- Receiver
- Sound-card
- Coaxial cable (RG-58, RG-8)
- 4 male BNC connectors, 1 male and 2 female N connectors
- 3/8" Copper tubing

2.2 Antenna Design

There are several design choices involved when constructing QFH antennas, especially regarding height of the antenna and materials used. It is extremely important to make sure that this structure is not unstable or weak since it has to withstand strong winds. All connections have to be held tightly so that there is no structural instability that would cause it to move and affect the signal receiving characteristics of the antenna. The reasons behind this design choice include easily available parts and detailed step-by-step procedure. The components required for this antenna are:

8 mm Copper Tube (10 meters)
8 mm 90 Deg. End Fed Elbows (10)
32 mm PVC Electrical tubing
Small selftappers (6)

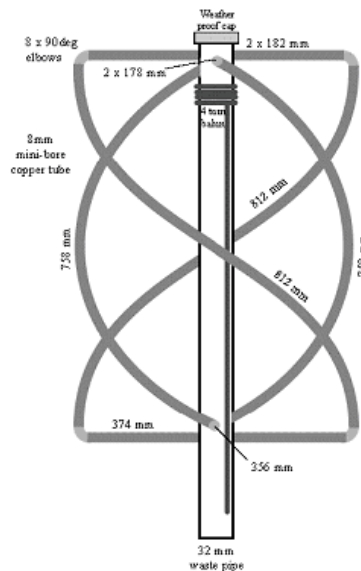


Figure 2: Physical dimensions of the antenna

Although a 1 m long PVC pipe would be fairly adequate to meet the requirements of this design, it was decided to use a pipe approximately .8 m longer in order to give it extra length that would be required for it to fit into the antenna mast. Regardless, there is a desire to keep it as long as possible in order to avoid the signal being blocked by buildings due to the antenna being too close to the ground. Although, leaving the structure too tall would leave it prone to strong winds. A PVC pipe is ideal for such a structure since it is considerably flexible and this helps in avoiding the structure from catching strong winds and reducing pressure on the pipe which would keep it from breaking off.

The copper tubes were cut to 812 mm for the large loop and 758 mm for the small loop. These copper tubes which would make up the partial helical components of the design were firmly held together in a bunch using cable ties. A cylinder that was approximately 300 mm in diameter and 2 feet long was used to bend the bunch by holding it against the cylinder and applying force on either ends of the bunch to bend the copper tubes. It is important to note that when viewed from the top of the structure these partial helices must rotate counter-clockwise as it approaches the bottom elements of the structure. Another pair of 182 mm copper tubes were cut to connect to two of the top four holes that would represent the large loop. Similarly, a pair of 178 mm copper tubes are cut to connect the small loop to the top end of the PVC pipe.

At the bottom end of this setup where both the loops end, two copper tubes were cut – a 374 mm tube for the larger loop and a 356 mm tube for the smaller loop. Next, a total of 8 holes were drilled into the PVC pipe. These holes were approximately 8 mm in order to accommodate the copper tubing. At one end of the PVC pipe 4 of these holes were drilled ninety degrees from each other. This would be the top end of the antenna where both the small and large loops are connected to the coaxial cable. All 4 holes sit on the same horizontal plane. Two holes were drilled 536 mm below the top four holes for the smaller loop and two more holes were drilled 560 mm below the top holes and 90 degrees away from the previously drilled holes for the larger loop.

At the bottom end of the loops the copper tubes are forced through the PVC pipe and hence there are only two tubes that make up the bottom element of the antenna. This setup is clearly shown in figure 2. The bottom element sections (356 mm and 374 mm) have to be secured tightly to the PVC pipe to prevent lateral movement. This can be done by using cable ties to hold the tubes tightly against the pipe. This can be avoided if the holes are drilled small enough to hold the copper tubes snugly instead of using cable ties.

An RG-58 coaxial cable was used in this design. Two holes were drilled approximately 70-80 mm below the top four holes for the coax cable to exit the PVC pipe, coil around it 4 times and re-enter the PVC pipe to be reconnected to both the copper loops (large and small) at the top end of the pipe. The coax could also be sent along the outer end of the pipe instead of inside the pipe.

The next step involves the procedure followed to make the connection between the coaxial cable and the copper elements at the top end of the PVC pipe. There are different approaches available to make this connection. Some use a printed circuit board that would neatly

make the connection between the coaxial cable and the copper loops. The approach taken in this design is quite different.

The first step is to cut a 1-inch long nylon plug to be used as the balun so that it would fit right into the top end of the PVC pipe. This would serve as the base to the connections that need to be made. As mentioned earlier, the tighter the plug fits into the PVC pipe, the better it is going to address structural stability issues.

Next, drill a hole down the center of this plug such that it is hollow enough (approx 8 mm) for the coaxial cable to pass through after coiling around the pipe. Next four holes of 2 mm are drilled at ninety degrees from each other, 4 mm in from the outer diameter of the nylon plug. 3mm holes are drilled 4mm from the ends of the four top copper elements. The whole nylon plug is screwed onto the PVC pipe to hold it in place.

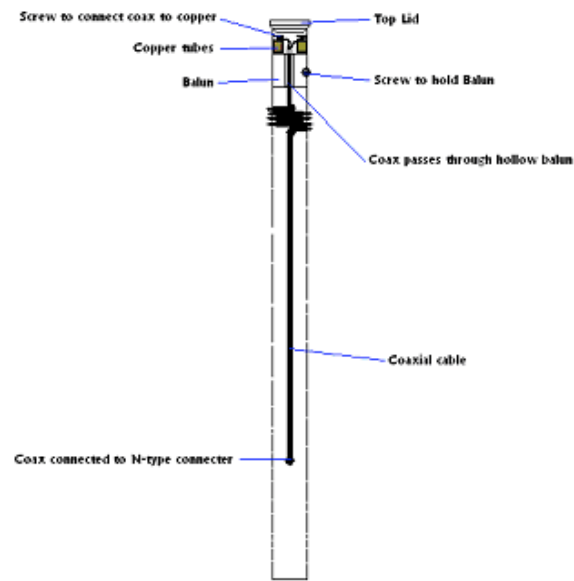


Figure 3: Interconnections of the antenna

The next step involves putting all the copper elements together and connecting them with 90 degree elbows. These elbows connect the bottom and top elements of the setup with the partial helical copper tubes. Another approach here would be to bend the copper tube itself instead of using 90 degree elbows. This was a choice made to avoid any error in the measurements that may be caused while bending the copper tubing. The most convenient way to solder the copper tubing is to attach one loop at a time and solder them individually since they tend to pop out of place until they are soldered. To solder the 90 degree elbows, soldering flux was first applied followed by applying solder and using a torch to set it in place. This was repeated for each 90 degree elbow till the complete structure was in place.

Next, the coax on top was wire stripped and the outer lead was split into two bunches, one for each loop element. Similarly, the inner conductor was split to be attached to each loop element. Consequently, each loop is connected to both the inner and outer conductor of the

coaxial cable. This connection is made via self-tapping screws that are put through the top copper elements and into the 3 mm holes that were drilled into the nylon plug. So the coax conductors are wrapped tightly around these screws. Extreme care is required when making these connections as the outer conductor of an RG-58 coaxial cable is rather thin and can be easily damaged.

The lower end of this setup consists of the coax hanging loose in the PVC pipe. A 15mm hole is drilled towards the lower end of the PVC pipe (but not too low as there has to be space for the antenna to fit into the tripod) where the cable is connected to an N-type connector which would serve as the output of the antenna. To fix this connector firmly onto the PVC pipe, Epoxy putty was used which takes about an hour to settle. The top end of the PVC was covered using another nylon plug cut such that it would fit snugly on top to serve as a cap. This would prevent any rain from entering the setup and damaging the connections.

The antenna is secured on the roof of Eaton Hall on a tripod. The tripod is installed by drilling two holes for each leg and secured with long screw into the roof. The antenna is placed on the tripod and secured with a screw on the PVC. The antenna mounted on the tripod is placed at a distance from big metallic objects to minimize interference and receive a better signal. The pre-amp is mounted on the PVC pipe and secured with plastic attached with duct tape to protect it from any water. The pre-amp is powered with a 12 V DC power supply, the power supply was soldered on the pre-amp.

The antenna is connected to the pre-amp through a RG-58 coaxial cable (male N to male BNC). The pre-amp is connected to a RG-58 coax (male BNC to male N) that goes into a connecting box, and connected to a RG-8 cable female N to female N that goes down into the lab and is connected to the receiver through a male to male BNC. The receiver is powered and connected to the sound card through an audio jack. On the output of the receiver a speaker that can be turned ON or OFF with a switch is connected to hear the sound of the FM demodulated signal when a satellite passes by.

3. Testing

3.1 Hardware Testing

Although a lot of the design of this system went into the Matlab decoding of the signal and the antenna design there were still many hardware issues that needed to be dealt with. One of the most important issues was after the antenna was built making sure that it was tuned to the correct frequency so that the satellite's signal could be received. This meant finding the reflection coefficient or the S_{11} parameter on a network analyzer when the antenna is connected to the input. To know if the antenna is tuned properly the reflection coefficient has to be as small as possible. If this were the case it would mean that the RF energy sent from the network analyzer is being radiated from the antenna instead of being reflected back to the source. It would seem somewhat odd to see how an antenna can transmit a certain frequency since this antenna is only being used for receiving but this test determines the resonant frequency of the

antenna which is the same for transmitting and receiving since the antenna consists of linear components. Connecting the antenna to the network analyzer provided the following plot.

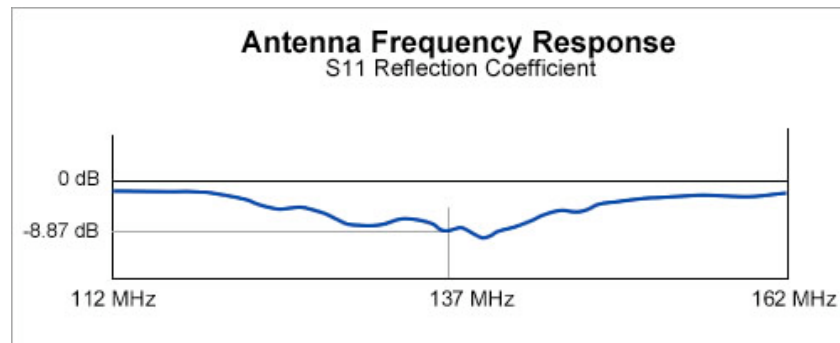


Figure 4: Frequency response of the antenna.

From this figure the reflection coefficient is very low around 137.5 MHz, which is the desired frequency. Although it seems to be lower around 139 MHz this antenna still performs well for our application. From this plot about 13% of the power is reflected back into the network analyzer and there is probably about 5 to 10 percent of the power lost due to resistivity of the copper tubing and the coaxial cable and connectors. So this antenna has a power efficiency of 80% to 82%.

The next piece of equipment to test was the RG-8 coaxial cable that ran from the 502 lab to the connector box on the roof. To determine the loss of the cable the network analyzer was moved from the 420 lab to the 502 lab on a cart. The spectrum analyzer showed that the line had 1.57 dB of loss which meant that the coaxial cable had a loss of .785 dB in one direction. Then there is 40 feet of RG-58 coaxial cable from the antenna to the connection box on the roof. This cable has a loss of 5.379 dB per 100 feet at 137 MHz. So for the 40 feet of cable used in this project there was 2.2 dB of loss. Although the signal would experience this loss, it would be easily overcome by the pre-amp.

The next device that was tested is the pre-amp used near the antenna on the roof. This pre-amp was tested by connecting the input to a high frequency function generator and the output to a spectrum analyzer. The specifications of the pre-amp say that the pre-amp should have about 18 dB of gain. Initial testing of the pre-amp gave 19 dB of gain. So the pre-amp was attached to the antenna with duct tape and plastic bags to keep the water from getting into the device. Then the pre-amp was connected to the connector box on the roof that sent a 50 ohm coaxial cable feed to the 502 lab. This cable was then connected to a spectrum analyzer to determine if a signal was being received.

After using the NOVA software to determine when a satellite would pass the next step was to wait for a signal to appear on the spectrum analyzer. No signals appeared. So it was decided to generate a 137 MHz signal using the signal generator that was used to test the pre-amp and a monopole antenna. The monopole antenna had a resonant frequency at 150 MHz. When the signal was transmitted it was visible on the spectrum analyzer. Then, the antenna feed was connected to the receiver to see if the receiver could receive the same signal. While testing the receiver it was noticed that some of the energy that was being sent from the signal generator

was coupling with the coaxial line that fed from the receiver to the connection in the 502 lab. Once this was realized, the signal generator was moved out into the hallway to block the coupling and the antenna and pre-amp were re-tested. This time it was unable to detect the signal so the pre-amp was removed from the roof and tested again.

When the pre-amp was retested it was found that when some pressure was kept on the connection, the original signal without any gain was achieved which is shown in the following plot.

When pressed together the original signal could be observed without any gain.

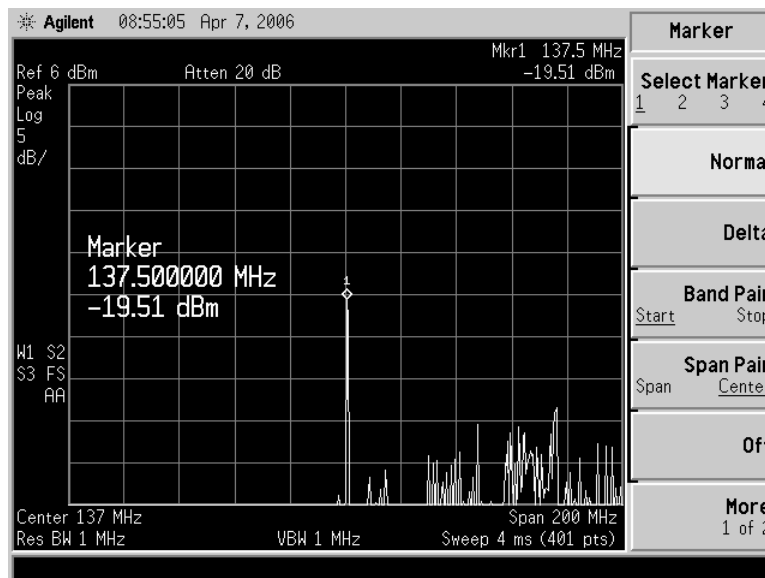


Figure 5: Output from the pre-amp when a -20 dBm signal was transmitted.

So, it was evident that there was a problem with the pre-amp. It was decided to open up the pre-amp and after looking at it with a magnifying glass, a small crack between the BNC connector and the circuit board was clearly visible. So at this point resoldering the connection between the connector and the circuit board was the best option and that gave the following response from the pre-amp.

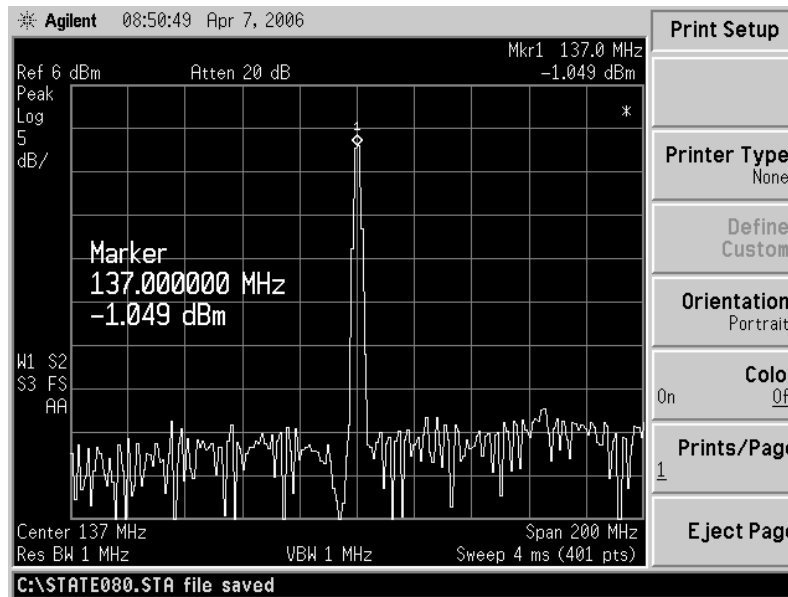


Figure 6: Output from the pre-amp when a -20 dBm signal was transmitted.

The pre-amp was then reconnected to the antenna with duct tape and the spectrum analyzer was used to detect a signal. When a satellite passed over head, the signal was detected with the spectrum analyzer and after that the receiver was able to pick up signals from different satellites.

3.2 Software Testing

Most of the software testing was done by debugging the code and making sure that it ran correctly. One of the major hurdles overcome was demodulating the AM sub-carrier. The different demodulation schemes used to decode the AM-sub carrier are discussed further in the Software Description.

One of the other testing procedures that was performed was to test the receiver sound card connection. To do this, the noise power was increased on the receiver by adjusting the squelch knob and the signal was recorded and played back on the computer. It was a relatively simple test and it replayed the noise signal.

4. Operation and Setup

4.1 Setup

The first part of the weather station that must be installed is the antenna. It is best to position the antenna on top of the roof of a building somewhere so that other buildings do not block the path between the satellite and the building. With the setup described in this project

signals were detected that were at an angle of ten degrees. This angle is between the tangential plane of the earth at the receiver's location and a line that ran from our location and the satellite.

Next the pre-amp should be connected as close to the antenna as possible and should be weather proofed so that the circuits are not destroyed by rain. This was done by using a Ziploc freezer bag and covering the pre-amp and then connecting the coaxial cables and the power. Finally, the pre-amp was wrapped inside of the plastic bag with a lot of duct tape to make sure no water gets in.

Then a cable needs to be run from the pre-amp to the location of the receiver and the computer. This was previously done since there was already a 50 ohm coaxial cable between the roof and the 502 lab. Then the cable is connected to the receiver and the receiver's audio output is connected to the microphone jack on the computer. Plug both the computer and the receiver into their power supplies. Some recording software needs to be installed on the computer along with Matlab to use the Matlab code to decode the signal. Also it is nice to have the NOVA satellite tracking software to determine when a satellite is going to fly over head, but it is not necessary because the receiver can detect the signal. It is also a good idea to connect a speaker to the receiver's output so that you can hear the tone when the satellite passes over.

4.2 Operation

To operate the receiver it should be turned on, and if the user knows which satellite is going to pass overhead then he should select the desired channel. If the satellite is not known, then the receiver should be set to scan all of the channels. Once a signal is detected the user should press the record button on the computer to record the signal until the signal is no longer present.

Then the Matlab code should be run and the user should follow the prompts by inputting the location of the wave file and then increasing or decreasing the contrast of the image and flipping it if needed.

5. Circuit description

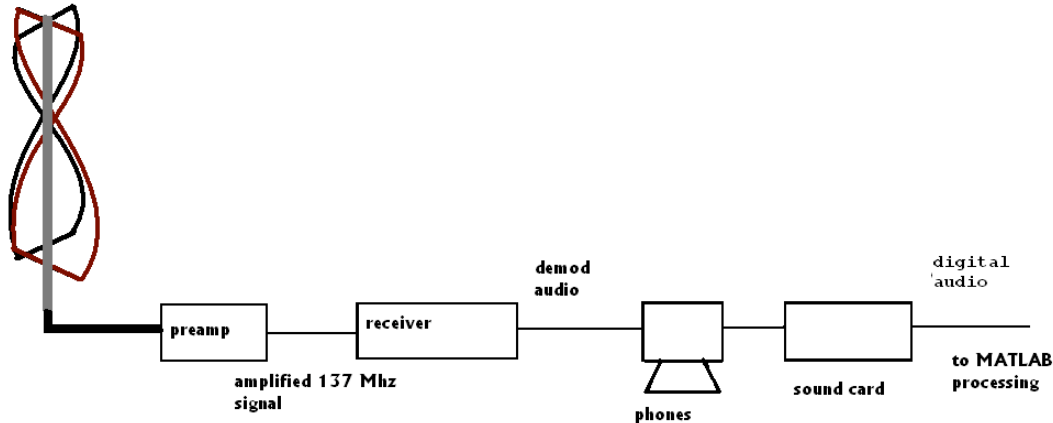


Figure 7: Block diagram of the hardware

5.1 Block Diagram

The block diagram shown above is the receiver chain that was used in this system. The signal enters the system through the antenna and is then sent to the pre-amp. The pre-amp is located close to the antenna to amplify the signal above the noise that will be introduced throughout the rest of the system. The receiver FM demodulates the signal and then sends the 2.4 kHz sub-carrier to the sound card and the computer demodulates and decodes the signal.

5.2 Functional description of the blocks

The signal that comes into the antenna and goes through a balun made of 4 turns of RG-58; this device is used to connect the balanced antenna (the copper helixes) to the unbalanced coaxial cable. The pre-amp amplifies the 137 MHz signal by about 18dB.

The amplified signal goes through the RG-58 and RG-8 cable down to the receiver. The receiver has 5 different channels, 137.100, 137.500, 137.620, & 137.9125 MHz NOAA satellite and 137.4 MHz Meteor Russian satellite. The scanning can be done manually or by setting the scan button on "SCAN"; this mode allows the receiver to scan automatically and whenever a satellite is transmitting a signal the receiver will stop on the proper channel and demodulate the FM signal to a 2400 Hz audio signal. This audio signal is then input into the sound card and converted to a digital signal, and then a Matlab program converts the wav file into an image.

6. Software Description

6.1 Theory of software operation.

After the signal has run through the antenna and the receiver that demodulates the FM carrier and leaves an AM sub carrier the signal is sampled using the sound card. The message signal within the AM sub-carrier is the data signal which contains the image.

The satellite transmits the data signal continuously as it orbits the Earth but the signal is only detectable when the satellite is in close range of North America. So this means that when the signal is detected by the receiver the satellite is transmitting an image that covers North America.

Every half a second a row from the image is transmitted and this strip of data is directly below the satellite. So if the satellite is traveling from south to north the image received will defy the normal convention of most of maps running north to south so the image will need to be flipped so that the user can easily interpret the image.

The other issue of decoding the image from the data is determining when each row starts. Each row of the image is transmitted every half a second but there are actually two images which are contained in each row of data. The first row that is transmitted is an image that uses the optical spectrum to create an image of the earth while the second piece of data comes from the infrared spectrum. This second row of data allows the satellite to image the dark side of the earth as it orbits.

So the message signal that is transmitted contains a synchronization pulse before each row of each image (optical and infrared) data so that anyone trying to decode the signal can determine the beginning of each row of data. Then after each row of each image is transmitted there is telemetry and thermal information transmitted. For this project this information was not used to decode the signal but in other software programs this data has been used to determine a point of reference to overlay political boundaries on the map or determine the temperature at a certain pixel.

6.2 Structure chart of the system.

In the system demonstrated in this project the signal that was output from the receiver was fed straight into the computer's sound card. Two reasons for doing this are that there are very user-friendly interfaces on the computer for capturing the signal as a wave file and importing into Matlab and the inexpensive and easily attainable nature of a computer sound card. This also allows other users of the software the ability to use this software without having to supply their own analog to digital converter. In the following block diagram the analog to digital converter will represent the computer's sound card sampling the information and Matlab decoding the wave file. Another important thing to note about the block diagram is that the thin lines represent a vector of information flowing between blocks while the thicker arrows represent a matrix of information flowing between each block.

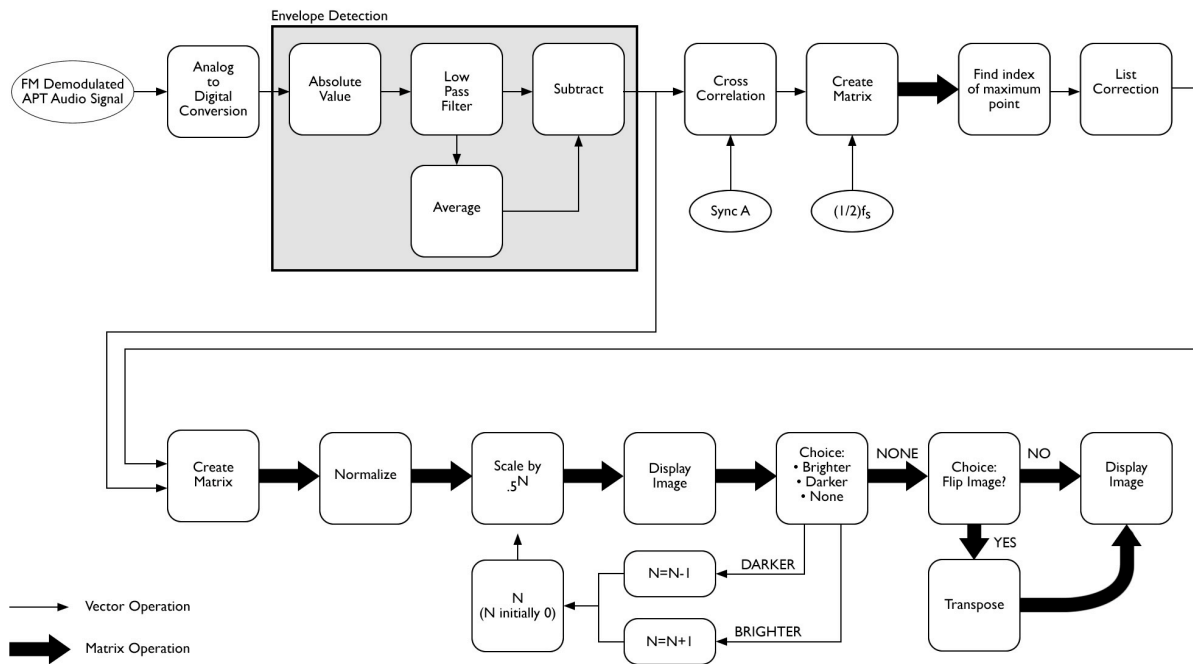


Figure 8: Block Diagram of decoding process of the AM sub carrier

After the signal is retrieved from the analog to digital converter the AM sub-carrier needs to be demodulated. The first way tried to demodulate the signal was by filtering the carrier with a bandpass filter and then using the filtered carrier in a coherent demodulation scheme along with a low pass filter to demodulate the signal. One of the problems with this method is the nonlinear phase of the filters and the delay caused by them. The following figure shows this demodulation scheme.

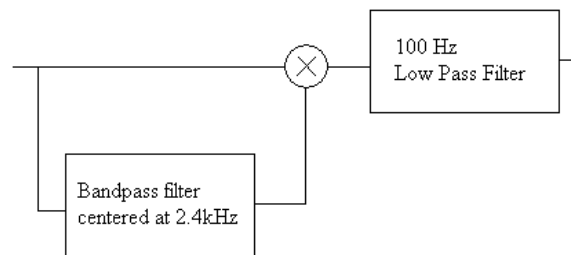


Figure 9: Block diagram of the AM demodulation using two filters

From this demodulation the image from Matlab appeared smeared and even smeared into the infrared image.

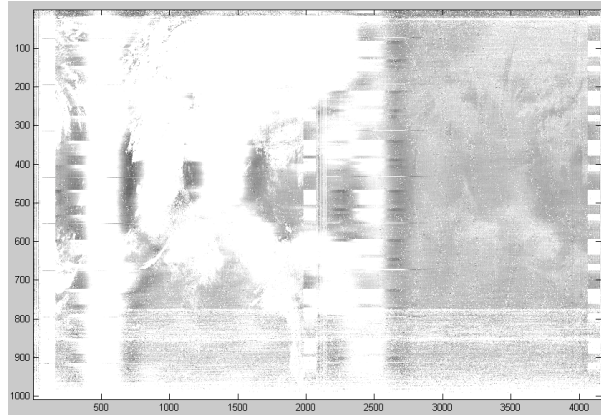


Figure 10: Smeared image using AM demodulation with filters.

From this image the time division markers are visible and the image is smeared from the non-linear phase of the filters. After trying this demodulation scheme with linear phase filters and trying to deal with the group delay we decided to use envelope detection. The envelope detection is shown in the following blocks.

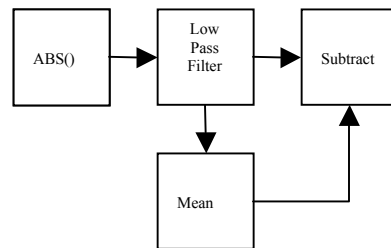


Figure 11: Envelope detector

This envelope detector starts out by taking the absolute value of the signal which acts like a rectifier. Then the rectified signal is passed through a low pass filter which is used to smooth the ripples of the rectified signal. Then the mean of the low pass signal is found and subtracted from the low pass signal to remove the DC component of the low pass signal.

One of the important characteristics of the low pass filter is the cutoff. If the lowpass filter has a high cutoff frequency the image will appear to have ripples across it and will not look as crisp. To eliminate the ripples the cutoff frequency should be set slightly higher than the highest frequency within the message signal.

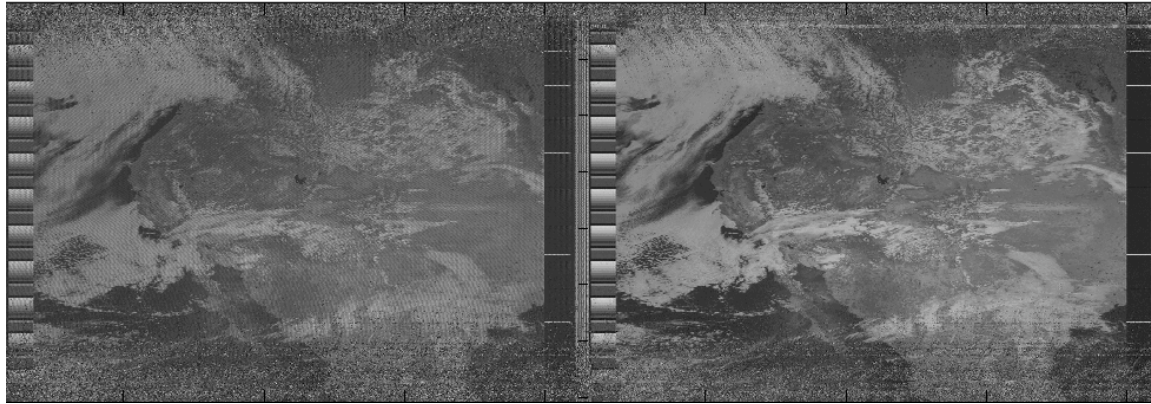


Figure 12: The picture on the right was demodulated using a low pass filter with a high cutoff frequency while the picture on the left was demodulated with a low cutoff.

The next part of the processing chain is the signal's cross correlation with the synchronization square wave. There are two different synchronization waves that could be used and in this project the wave that synchronized the optical image was used so the optical image would appear first after processing. The synchronization that corresponds with the optical image is sync A and is featured in the following diagram taken from the NOAA website.

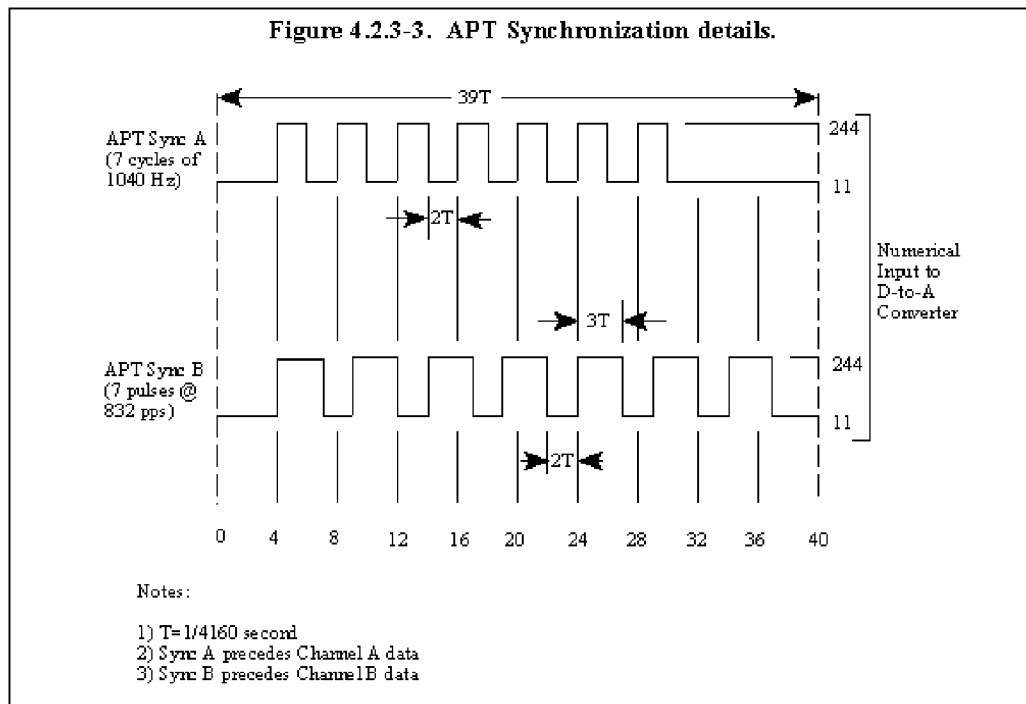


Figure 13: Characterization of the synchronization signal from the NOAA website.

The maximum point in the cross correlation with the demodulated signal would tell exactly where the signal ended if the signal had a suitable signal to noise ratio. The following plot is a cross-correlation with a received signal to give a demodulated signal.

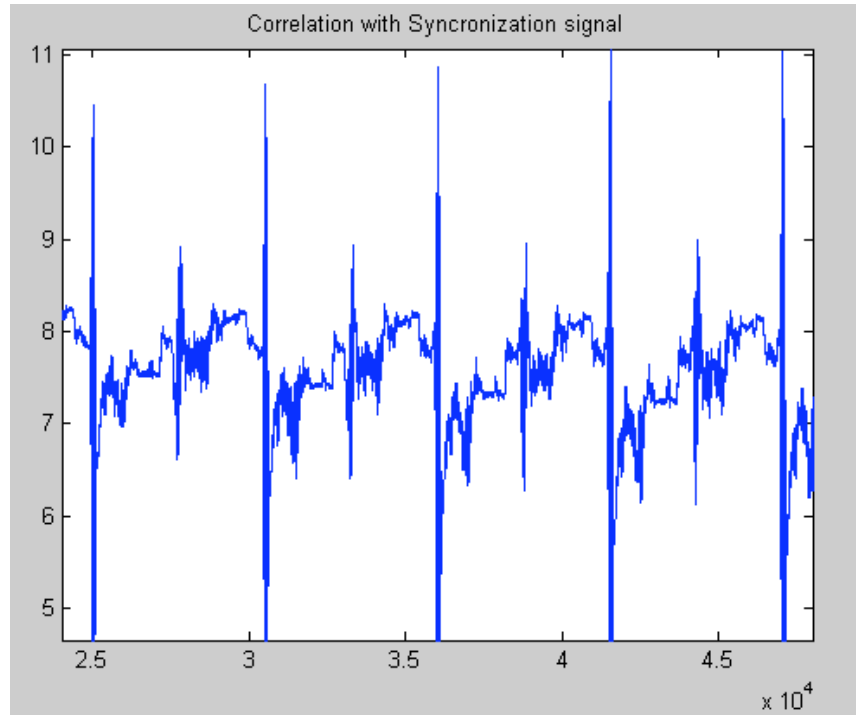


Figure 14: Cross Correlation with demodulated signal

In this diagram the large spikes occur every half second which is how often the signal is repeated. Another important characteristic about this wave is that the second highest point occurs a quarter of a second after the highest point which shows that there is a significant correlation between synchronization pulse A and B which there should be since both pulses are periodic and have periods which are proportional by an integer value.

After the cross-correlation is found the signal is then divided into sections that are half the sampling frequency long in samples. Since there will only be one large correlation per section the index of the correlation pulse can be determined and this value is placed into a vector this vector will be referred to as the list of index points. This occurs in the create matrix and find index of the max point blocks.

Then another vector is created using the list of index points by shifting the list of index points and shifting the index of the list of index points by four indices and then subtracting the shifted list of index points by the unshifted list of index points. This new vector, which is called the test vector, determines the spacing between the max correlation point and the max correlation point that is 2 seconds away. There are two reasons why we would want to do this. The first is that it will allow us to determine if the max point in the correlation pulse is actually the end of the sync pulse because there will be a lot of noise at the beginning and end of the signals that come out of the receiver and we would like to find the first actual ending of a synchronization pulse which would occur two seconds after another synchronization pulse. The other reason is that sometimes there is some interference with the signal and while satellite is in a good location to receive the signal so if a synchronization wave has too much interference to detect it could be detected and then interpolated from other synchronization points that are known to be good.

This leads us to the next block in the signal processing chain which is the list correction block. In this block the test vector is searched to find the first value that is within ten samples of twice the sampling frequency. Once that value is found the index at that point is put into another list of good index points. Then the next value in the test vector is inspected. If this value is within 10 samples of twice the sampling frequency then its value is placed as the next value of the good index points. If this value is not the next good index point it is thrown away and the last known good index point is added to the product of half of the sampling frequency and the number of bad index points since the last good index point. This block detects any inconsistent correlation points and then interpolates these points with known consistent index points and places them in the vector known as good index points.

Then the demodulated signal and the good list of index points are sent to the next block which is called create matrix. This block uses the index points from the good list of index points and takes sections of the demodulated signal that starts at the points listed and ends half the sampling frequency later and place these sections into a matrix. This matrix is the data that is used to form the image and will be referred to as the raw data matrix.

This data in each row is then resampled so that there is the correct number of data points in each row to form the picture. Then the data points are normalized so that they range from 0 to 255 which happens in the normalization block. These data points are then displayed using the image command in Matlab and viewed by the user.

The user is then asked if the image needs to be brighter or darker and the brightness or darkness is controlled by increasing or decreasing an integer number which is the exponent of the scaling factor. This number is initially zero and then changed by the user. Once the user is satisfied with the contrast he is then asked if he would like to flip the image so that the top of the image refers to north and the bottom of the image is towards the south. Once these functions are completed the final image is displayed on the screen.

7. Summary

The system described in this report was created and able to receive and demodulate and decode an ATP signal. The image received was clear and important landmarks were distinguishable when not covered by clouds. The overall goals set by the team were accomplished in this project.

8. Reference

Satellite Tracking

- NOVA software - <http://www.nlsa.com/index.html>

Satellite Imaging

- Remote Imaging Group - <http://www.rig.org.uk/>

Antenna Design

- Amplification
 - Pre-amp - <http://www.hamtronics.com/> (click on the VHF pre-amp link)
 - Cougar Amps - <http://www.techsavvy.com/industry/file/national/10csj/cou04.html>
- Quadra-helix antenna - <http://www.qsl.net/kf4cpj/qha/>
- Antenna - http://homepage.ntlworld.com/phqfh1/qfh_diy_guide.htm
- WXSAT QFH - <http://www.frars.org.uk/cgi-bin/render.pl?parameter=&pageid=1154>
- Design - http://perso.wanadoo.es/dimoni/ant_qha.htm

Signal Processing

- NOAA Signal Specs - <http://www2.ncdc.noaa.gov/docs/klm/html/c4/sec4-2.htm>
- Taggart, Dr. Ralph E. - Weather Satellite Handbook - American Radio Relay League

9. Appendix

Antenna Measurements	
Copper Measurements:	
Large Loop:	
Upper Element:	2 x 182 mm
Lower Element:	356 mm
Partial Helicals:	2 x 812 mm
Small Loop:	
Upper Element:	2 x 178 mm
Lower Element:	374 mm
Partial Helicals:	2 x 758 mm
90 degree elbows	8
PVC pipe	32 mm
Coaxial Cable	RG – 58

Frequencies associated with each receiver channel	
Channel	Frequency (MHz)
1	137.100
2	137.400
3	137.500
4	137.620
5	137.912

Receiver Specifications				
Model	Tune Range	Typical Noise Figure	Gain	Min. 3 dB Bandwidth
LNK-137	130-160 MHz	0.6 dB	18 dB	+/- 4 MHz



Figure 15: Antenna connections to the coaxial cable.

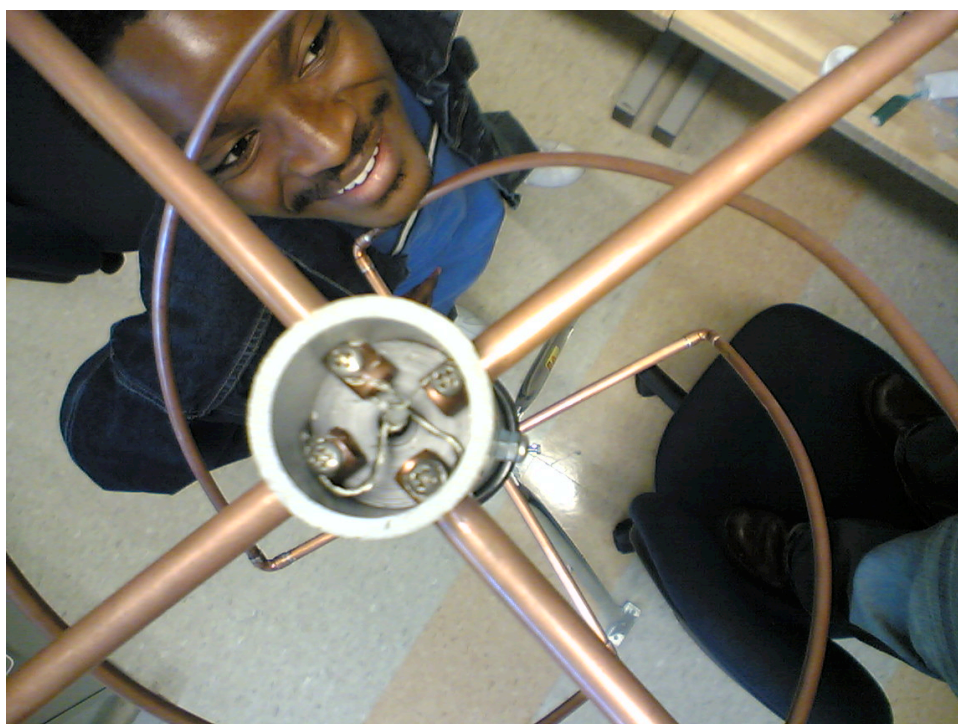


Figure 16: Eric checking out the curves on the QHF antenna.



Figure 17: Upper half of the QHF antenna without a cap.



Figure 18: N-type connector attached to the antenna using Epoxy.



Figure 19: (Left to right) Mark, Eric, Vijo, Bill standing next to the QHF antenna.