Weather Satellite Receiver 2015 Proposal

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www.wsr2015.wordpress.com

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OUR TEAM & RECOGNITIONS

Our team is made up of three members: Alyssa Afa'ese, Joe Goren, and Alberto Martos; all Senior Electrical Engineering students at Sonoma State University. We are currently enrolled in ES 492: Senior Design Project Planning and plan to take ES 493: Senior Design Project during the final Spring semester of our undergraduate career. We also would like to thank the rest of our Engineering faculty and staff at SSU for their patience, knowledge, and encouragement throughout the years. Additionally, we would like to thank our fellow peers for their crucial companionship and endless assistance during the course of our undergraduate studies.

MOTIVATION & RESEARCH STATEMENT

As we all know wireless communication is one of the most widely used forms of communication today. Additionally, radios and transceivers, serve as an integral part of transmitting and receiving data within a wireless network. With that said, our group aims to create an improved and cost-efficient RF automated picture transmission (APT) receiver which will ultimately gather information from National Oceanic and Atmospheric Association (NOAA) satellites. The gathered information will then be readily available as satellite images for personal use or for the public for a lifetime. Specific satellite applications that may find use in our product range from cubesats collecting scientific data, manipulating geographic images for land use, or even military satellite applications. With improved design techniques our receiver will efficiently produce weather satellite images at much lower production costs than traditional commercial receivers.

BACKGROUND

Antenna: The quadrifilar helical antenna was patented by two gentlemen in Los Angeles, California during 1994. More importantly, the quadrifilar helical is an antenna with 4 radiating helix elements attached to a micro-strip that serves as the mast, which also contains the transmission line. Commercial grade products are known to use high-class copper, ABS radome, stainless steel, as well as teflon materials. However, many hand-made helical antennas have been used in applications for years and are made with everyday materials. This makes the antenna widely known for its easy build and construction with a wide range of operation. This antenna is also known for its omni-directional and perfectly circularly polarized radiation pattern in all directions. Since these antennas produce such great coverage they have been used in various GPS satellite applications; i.e: weather, geographic. As a complement to our system, the quadrifilar helical antenna will be attached to the front-end for sufficient receiving of FM signals. They continue to serve as a great basis for many satellite applications today and can be found in personal ground stations.

Micro-controller: One major design improvement that will be made is the addition of a micro-controller (MCU) and a display interface to the system. MCUs are effective tools that have opened the doors to many possibilities in electronics. Depending on the chip model, there are hundreds of functions that can be programmed. The main input to the micro-controller will be taken from the MC13135 FM IC which we will be utilizing the RSSI output of for determining signal strength. Under normal operation, the micro-controller will be cycling through the available channels by sending a high level signal to the channel oscillators. Once a signal is detected by the FM receiver, a signal will be sent to the MCU. In this scenario, the micro-controller will stop cycling through the channels and will lock into the one that is being received until the signal disappears after the received report. This is done by sending a high level signal to the individual oscillator. Specifically we will be using the Arduino Nano for all main functions which will communicate to a breakout board provided by Adafruit which utilizes an oscillator chip, Si5351. The Arduino Nano will be programmed in C language as well and supports any future expansion of the WSR2015 . The MCU will allow for different modes of operations tuning to Weather Satellites (NOAA), the National Weather Report (NWR) channels, FM stations, as well as a Variable Frequency (VFO) mode for all stations. The entire radio will be powered by USB and will have an audio output to allow CPU connection. This will allow for the transfer of NOAA audio signals to be converted into APT weather satellite images through software. The user will then be allowed to save or use the weather satellite images at their leisure.

IC Chip: The heart of this radio is based on the second generation receiver IC, the Motorola MC13135 chip. This IC includes a dual-stage mixer, limiting amplifier, quadrature discriminator, active filter, squelch, scan control and mute switch all in one unit. This particular circuit has been around for a few decades now and it is a very popular unit that can be found in almost 75% of all FM radio receivers, scanners and walkie-talkies in the market. Because of its versatility and a simple application circuit that only requires a few external components, it is a great choice for a weather satellite receiver. In fact, the IC by itself could be used to build a simple FM receiver. In our project, it will be connected to a RF front-end circuit composed of a RF amplifier stage and an IF and mixer stages. The oscillator will be provided with the lab equipment, then a mini-circuits module, and finally our own crystal controlled oscillator. The ideal setup will include the most common frequencies of the currently operational weather satellites, but no more of four or five channels to keep the simplicity and costs down. In addition, the front-end circuit will use dual gate FETs and no interstage IF transformers, which significantly simplifies the whole building process and final adjustments of the receiver portion. The versatility of this circuit allows to further expand the capabilities of the receiver and it will be able to receive commercial FM, air bands, and any other application requiring narrowband FM operation and reception. One of the most interesting applications would be to use it to receive signals transmitted by a CubeSat since its design is ready for satellite reception of any kind. The only modification to consider would be the antenna requirements which will vary according to the frequency of operation.

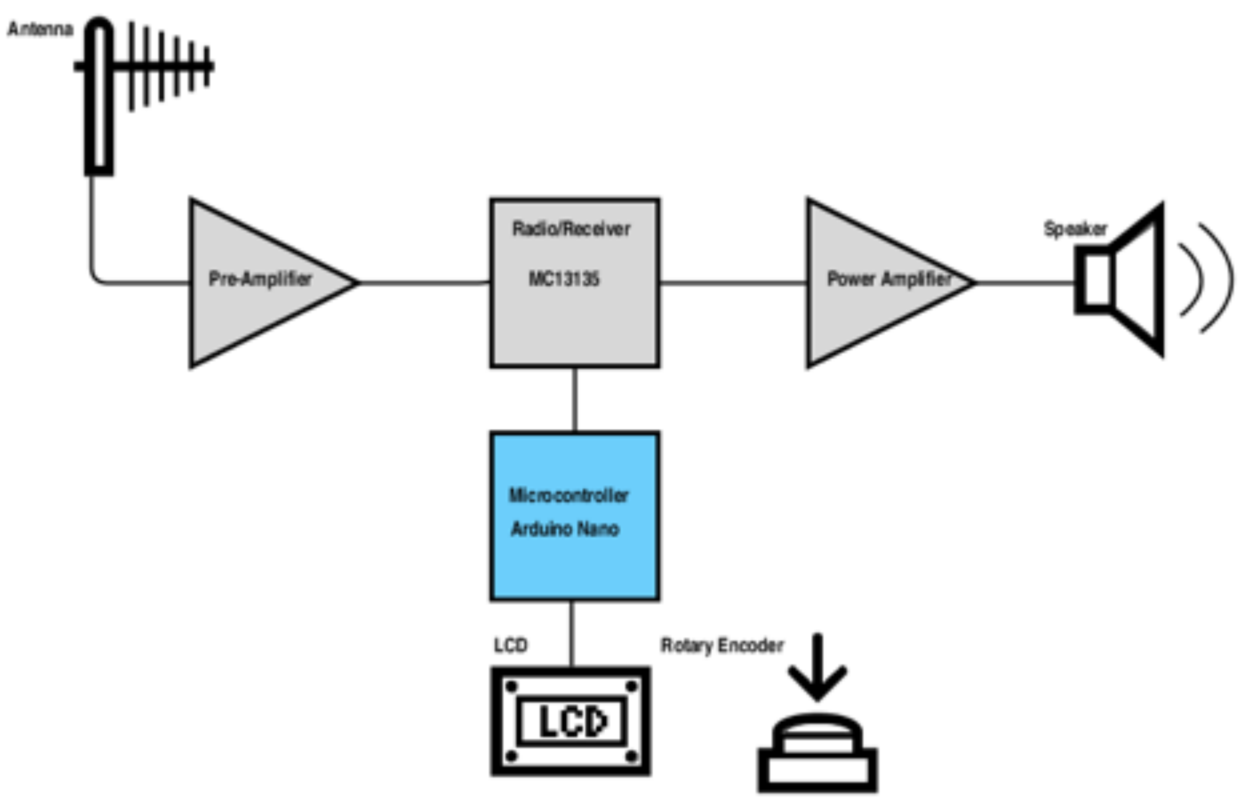
DESIGN APPROACH

The satellite receiver will largely borrow from the Motorola application notes and EME117 weather satellite receiver design by Minikits, but with major improvements and modifications. These additions involve, but are not limited to the addition of a micro-controller, a 2x16 character LCD display, menu, additional reception modes, a speaker monitor, and a quadrifilar helical antenna to complement the system. It will be divided into individual building blocks, with the output addressed and built first and ending with the input segment. This will allow us to correct any problem that might arise without compromising our timeline for the project. The major building blocks are the audio amplifier, FM receiver IC, RF front-end, micro-controller and LCD interface, and quadrifilar helix antenna optimized for 137 MHz. Each group member will be assigned specific aspects of the project to be in charge of, but no part will be without the aid and advice of the entire group. A traditional speaker will be used at the output to allow for the simultaneous monitoring of the received image and to be ble to listen to the FM and NWR channels as well. The received signals will be decoded through software which will ultimately display the captured images onto a computer. Additional software will be used to help track the satellites and receive the report at the optimum time of the day. A quadrifilar helical antenna has been chosen because of its omni-directional radiation pattern and circular polarization, which is great for receiving moving satellites while covering the whole sky. This allows us to avoid using a more complicated mechanical satellite tracking device. Additional antenna designs will be considered over the course of the development, such as micro-strip patches and cross-dipoles. The radio will have a user interface via the LCD screen and rotary encoder, all programmed into the MCU. A main menu will display the four options: weather satellite receiver (WSR), National Weather Report (NWR), commercial frequency modulation (FM), and variable frequency oscillator (VFO). The receiver chip, MC13135, allows us to achieve all these goals in a reduced area. This IC is a second generation Motorola receiver that exhibits great noise characteristics and quality of reception with a minimal component count. Being a dual conversion receiver, the first intermediate frequency will be 10.7MHz. A 230 KHz wide ceramic filter will be used for the first stage while a 30KHz wide filter will be used at the output of the second IF, which is 455KHz. Although this makes the second filter to do most of the job, this bandwidth is found to be enough for proper satellite reception and similar commercial receivers achieve great results with similar values.

Because of the local oscillator IC limitations, we chose to use low side injection in all modes but the satellite reception one. This allow us to receive a wide range of frequencies while still within the capabilities of the programmable oscillator.

BLOCK DIAGRAM & SCHEMATIC

This is a high-level block diagram of our full weather satellite receiver system. The front end on the left is the antenna, in this case the quadrifilar helical antenna which will connect to the pre-amplifier input. The pre-amplifier will amplify the signal enough for the receiver to detect which will then be fed inside the mixer of the of the radio chip to achieve the desired frequency. The radio is also seen below attached to the micro controller which is controlling and tuning to different frequencies. The micro controller also feeds to an LCD which will display our menu and its options, as well as a rotary encoder which will essentially control the menu. A power amplifier will be attached to the audio output of the radio which will then attach to a speaker.



On the next few pages you can find three separate schematics of the circuit design to our system. The first one shows the RF preamplifier with an output to the receiver. The second schematic shows the main part of the system, the receiver or the radio, as well as the audio amplifier. The third schematic will show the micro controller interfaced with the LCD display. With the system being complex we decided to create three separate schematics to thoroughly show the full circuit design to our system.

***If you are viewing this via our website, please find the schematic links on the homepage.**

PROJECT COST

Summarization: *Note: Parts may be ordered and added to this list in the future*

Item	**Quantity**	**Total Cost**
Edge-Launch SMAConnector (1.6mm)	1	$2.50
PVC Pipe (1in x 5ft)	1	$3.05
Copper Rod	17ft	$16.83
Rotary Encoder	1	$4.50
Adafruit Si5351A Breakout Board	1	$7.95
1pF Ceramic Capacitor	4	$0.55
3.9pF Ceramic Capacitor	1	$0.11
4.7pF Ceramic Capacitor	1	$0.11
5.6pF Ceramic Capacitor	3	$0.55
6.8pF Ceramic Capacitor	1	$0.14
10pF Ceramic Capacitor	2	$0.27
12pF Ceramic Capacitor	1	$0.14
47pF Ceramic Capacitor	1	$0.14
120pF Ceramic Capacitor	1	$0.11
390pF Ceramic Capacitor	1	$0.11
1nF Monolythic Ceramic Capacitor	4	$1.64
10nF Monolythic Ceramic Capacitor	3	$0.68
47nF Monolythic Ceramic Capacitor	1	$0.25
100nF Monolythic Ceramic Capacitor	8	$1.24

1uF Electrolytic Ceramic Capacitor	3	$0.61
4.7uF Electrolytic Ceramic Capacitor	1	$0.16
10uF Electrolytic Ceramic Capacitor	5	$0.25
47uF Electrolytic Ceramic Capacitor	2	$0.29
5Kohm Trimpot	1	$0.36
10Kohm Trimpot	2	$0.73
20Kohm Trimpot	3	$1.14
50Kohm Trimpot	2	$1.00
100Kohm Vertical Trimpot	1	$6.36
MC13135P	1	$2.41
MC34119P	1	$0.23
BC547B	1	$0.27
BC549C	1	$0.77
BF998 Dual Gate MesFET	1	$0.91
TL072CP	1	$0.55
1.0uH RF Choke	1	$1.20
10.245MHz	1	$1.50
180pF Ceramic Capacitor	1	$0.11
808 Trimmer 1.4-5pF	1	$2.14
2.54mm 3 Way Header Socket	4	$0.14
2.54mm 2 Way Header Socket	1	$0.55
2.54 2 Way PCB Header	1	$0.36
2.54 3 Way PCB Header	1	$0.14
2.54 HDS Terminal Pin	1	$0.60
E526HNA-100073	4	$8.00

455KHZ I/F Transformer 10mm	1	$2.09
CFU/LTU455B2 Ceramic Filter 455KHz	1	$2.36
Ceramic Filter 10.7MHz 230kHz BW	1	$1.00
Total		$77.10

PROJECT ROLES

Alyssa will be mainly focusing on the antenna on the front-end. The chosen antenna was the quadrifilar helical antenna for its sufficient coverage as satellite passes only occur every so often around the globe. The antenna will be modeled and simulated to ensure its radiation pattern to is within the frequency of our operation through software. Ideally, after simulating and modeling the fabrication of the antenna will take place. The finished antenna will be tested on the network analyzer and adjusted accordingly based on results. Although other antennas may be built and tested, the quadrifilar helical antenna is

Joe will be responsible for the micro-controller unit addition to the system. It will be programmed to take the Control Oscillator Switch signal from the radio chip and provide automated scanning and lock functions for the oscillator. Its logic gates will choose the correct oscillator to mix with the incoming RF signal from the satellite, creating the 10.7 MHz IF data. Additionally, the micro-controller will program a LCD display as an interface for the user to view the channel switching and locking to a particular satellite signal.

Alberto will build the FM section with the Motorola MC13135 IC. Also, as the project goals are full-filled, he will expand the project and build also the RF front-end section. He will also produce a complete PCB to host the project neatly.

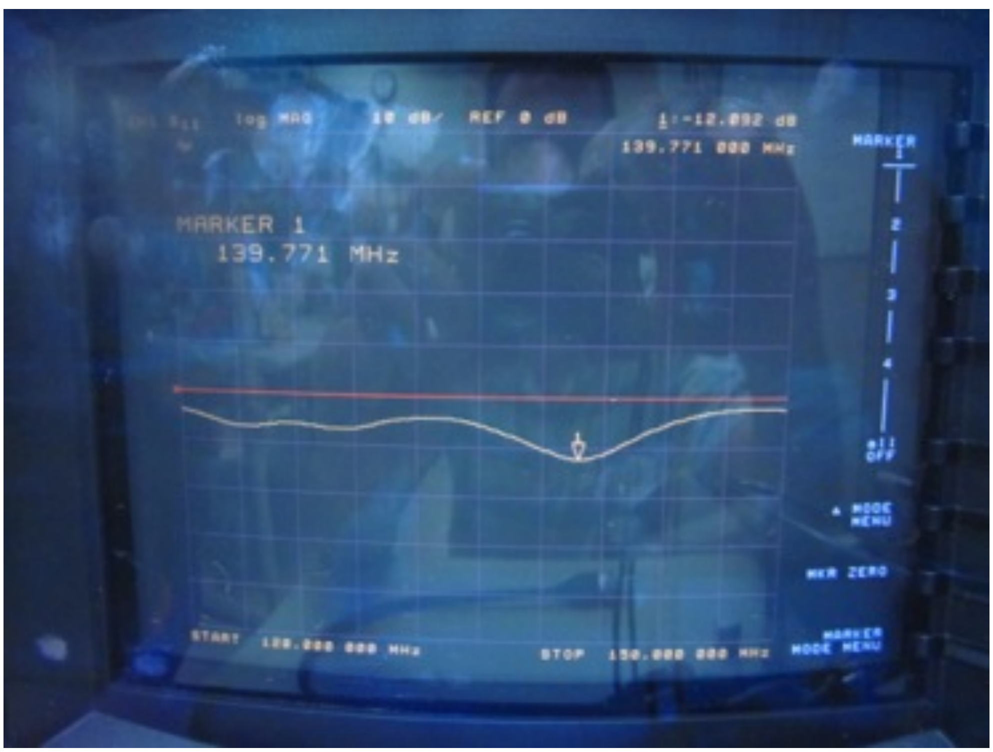
DESIGN CHALLENGES

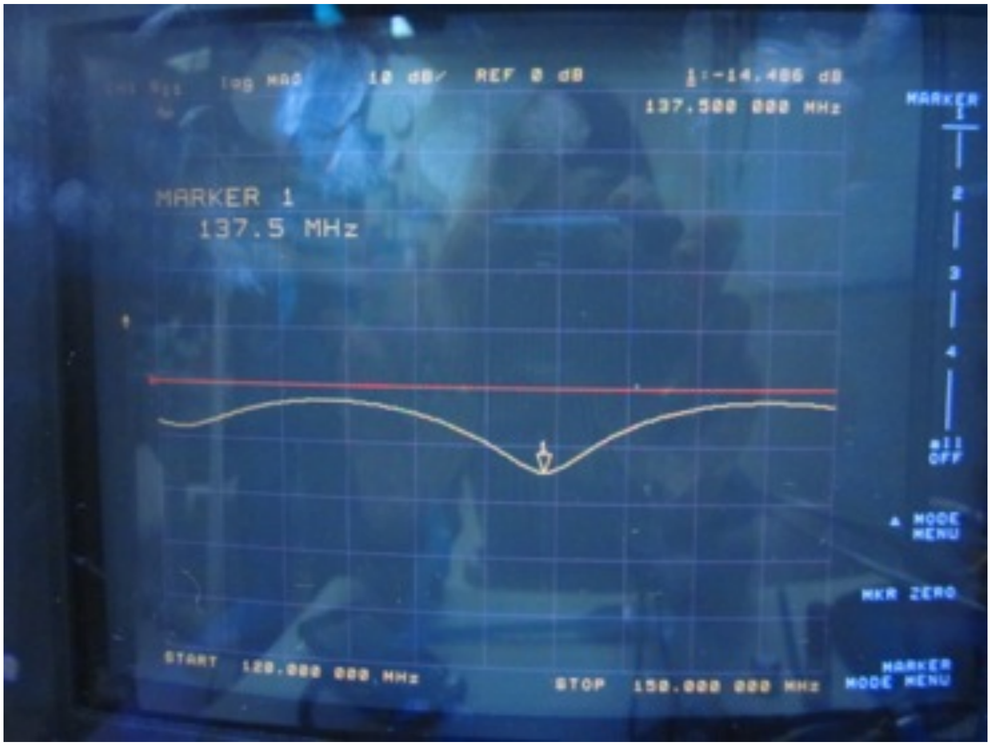
Hardware: Design challenges that will present themselves in the hardware side of the WSR encompass almost all aspects of the project. Also, minimizing noise to be received will require careful layout of the components. Another challenge to overcome will be to learn the proper setup to receive the weather images. The time frame is very limited and it requires prompt action to download the image. Objects, buildings and trees block reception at low angles of elevation and they will have to be considered to avoid interference in the images. A well-designed radio chip that has a mixer and other features will be added, but externalities such as amplifiers must also be of good quality and not produce considerable noise of their own. One more challenge for our group would be designing the circuit board everything will be mounted on and the casing for the receiver. Beyond aesthetic appeal, we must minimize space, have the radio sturdy, provide adequate shielding, and an easy to use user interface.

Software: Our software design challenge comes in two forms; making a simple and efficient menu for the user to navigate the options of the radio and programming the variable oscillator to produce a precise frequency mix with the incoming RF. The menu needs to have a logical process to allow for the user to choose one of the four options, automatically display the received signal strength, scan for strong signals when indicated, and return to the menu when selected. A programmable oscillator will be used for this design. Locating a proper candidate requires extensive research and some ICs require special libraries to operate. For this reason, different models will have to be tested to ensure feasibility, requiring changes and adaptations to be made as the project progresses through development.

TEST RESULTS:

Current Antenna Test Results: These snapshots below show the S11 for the first prototype of quadrifilar helical antenna built. As you can see at 139.7MHz we have an S11 of -12.092 dB, while at our desired frequency 137.5MHz we have -14.486dB. As a first prototype, the quadrifilar helical seemed to have a sufficient return loss at 137.5MHz, although some modifications will be done to improve the antenna performance. Ideally we would like to increase the S11 value shown below at 137.5MHz, although sufficient results may be achieved once our pre-amplifier is ready and built. Note that we are using a RG-8X coax, a low-loss cable that handles high-power, along with a PL-259 connector which is widely used for UHF. There has been trouble particularly modeling and simulating this quadrifilar helical antenna through software, however in the near future it will be done as to assist us with our modifications.





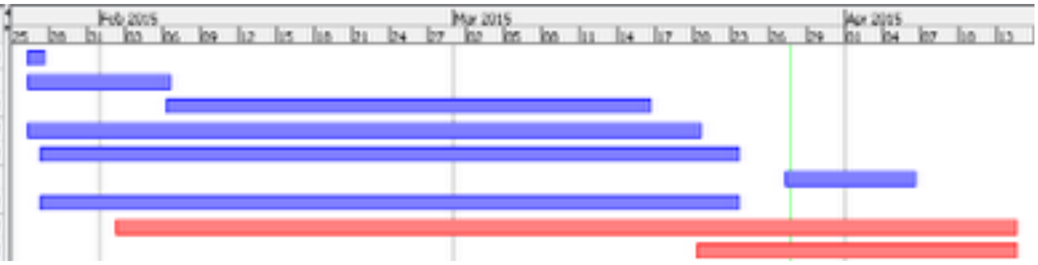
- Current Hardware Test Results: 89mA on average and 96mA total including the Arduino

Components	Consumption
LCD	8mA
Radio & Oscillator Circuits	24mA
Microcontroller	64mA

GANTT CHART:

A current Gantt chart of our major and minor milestones:

	Name	Duration	Start	Finish
1	Research for parts	2 days	1/26/15 8:00 AM	1/27/15 5:00 PM
2	Order Parts	10 days	1/26/15 8:00 AM	2/6/15 5:00 PM
3	Radio Circuit	27 days	2/9/15 8:00 AM	3/16/15 5:00 PM
4	MCU Interface	40 days	1/26/15 8:00 AM	3/20/15 5:00 PM
5	RF Front End	40 days	1/27/15 8:00 AM	3/23/15 5:00 PM
6	Audio and Tape output	7 days	3/27/15 8:00 AM	4/6/15 5:00 PM
7	Wideband Antenna	40 days	1/27/15 8:00 AM	3/23/15 5:00 PM
8	Testing and Troubleshoot	52 days	2/3/15 8:00 AM	4/14/15 5:00 PM
9	Improvements	18 days	3/20/15 8:00 AM	4/14/15 5:00 PM



RISKS

As with any high frequency circuit, there are some associated risks. One of the main concerns will be to correctly decouple all RF stages. This will be done by ensuring the component layout does not allow for cross-talking and oscillations and by keeping signals independent from each other. Ferrite beads will be used throughout. If instability occurs, the local oscillator might have to be enclosed in a mu-metal case to avoid those potential problems. Since the whole project will be implemented in stages beginning with the output stage, we will have time to rectify individual sections according to the results. Another source of risk will be the RF front end of the radio block. Since it is a very sensitive part of the project, there could be instability problems like the other stages. In the initial stages of the project we will be using mini-circuits modules, which will discard the possibility of errors on those stages. If instability occurs after the module is built, we would go over the PCB design and correct the problem areas by improving their layout or adding extra shielding. The micro-controller and LCD display will have very limited risks since we will have the opportunity to test the code on the development board before the final design will be implemented. The only source of problems could be coming from the MCU clock crystal oscillator. This crystal might interfere with the operation of the radio. If that happens we would either use an internal oscillator, ceramic resonator or modify its fundamental frequency so it does not interfere.   For the antenna construction there are some problems that may arise as well. Small variations during the fabrication process can lead to a design that does not resonate at the intended frequency. If this happens, we would have to trim and adjust the antenna elements until we make it resonate at the desired frequency. Also, we will not solder the coaxial cable completely to the receptacle and elements until the antenna behaves as intended. This allows for fine tuning the unit before the final product is built.

SOCIAL & ENVIRONMENTAL IMPACT

Our product will ultimately raise awareness for consumers by utilizing weather information provided by global NOAA satellites. The NOAA, or National Oceanic and Atmospheric Association, is a federal agency that studies the global conditions of oceans and atmospheres all throughout the globe. Consumers will be able to raise their awareness of weather conditions at any point along the globe by analyzing such images provided by the NOAA satellites. This will ultimately keep consumers updated on changes in the environment around them and will continue to serve as a basis for weather prediction. An ideal example would be national disaster information that is extracted through image processing procedures produced by NOAA satellite images.

NEAR FUTURE ADDITIONS & IMPROVEMENTS

The design strategy we plan to use leaves room for some major and minor improvements. Ideally, we would like the captured images to be pushed to dynamic web-server that will be updated in real-time. This will be accessible by all end-users who may find use of our images in a variety of different fields for a lifetime. Another improvement would be creating our receiver to work on tunable frequencies and allowing it to operate within other satellite frequencies. This is important as we have cube-sats created within the Physics department who may find critical use in our product and may want to expand on this. This will not only portray traditional commercial receivers, our product will also encourage many interdisciplinary projects within Sonoma State; i.e: geography, physics, ENSP etc. Another nice addition would be making a GUI interface where users will be able to control the radio/receiver through LabView, a software that the EE department provides.

COURSES:

ES 330 – Electronics II
ES 430 - Electromagnetism
ES 485 - Antennas
ES 310 – Microcontroller Design
ES 443 – Wireless Communications
ES485 - Networking

REFERENCES

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