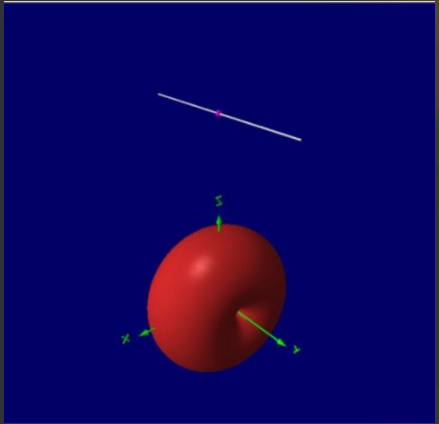
1.02 4NEC2/SDR HF Antenna

Our project is the use of free open source software to design, construct, and verify a multi-band HF antenna which receives via Software Defined Radio on a laptop. The software simulation is important because it is open source software which allows us to model relevant design aspects of our antenna in order to receive the amateur radio bands using a specific geometry. HF antennas are important because they require no satellites, internet, or undersea/landlines to transmit to a receiving station over the horizon. This project will facilitate the simulation of electromagnetic structures by future TX State students at no cost.

Fig. 1: Jorge Drew Roberto Dennis

Function	Deliverables	DRI
Simulate Antenna	Geometry, Impedance, Radiation Pattern, Antenna Coding, Simulation output	Jorge
	SWR, Smith Charts, S11	Drew
Setup/Confirm SDR	HF Operation Confirmation	Roberto
	SDR software setup, HF unlock, Software operations	Dennis
HF Antenna Setup	Materials, Fabrication, Assembly, Characterization with VNA	Roberto

1.02: Using 4NEC2 Electromagnetic Code For HF Antenna Design



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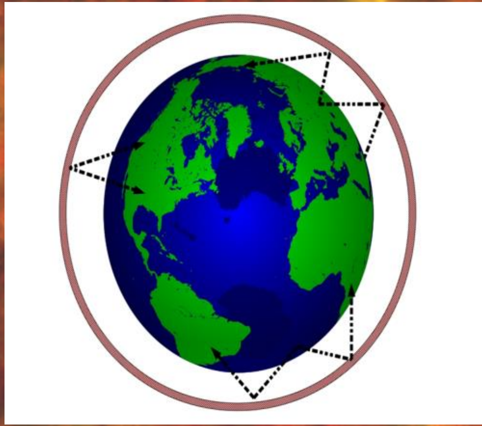


Initial Design Review

Sponsor: Texas State Ingram School of Engineering, Dr. Compeau

Faculty Advisor: Dr. Karl Stephan

PROJECT OVERVIEW

- WE ARE DESIGNING A MULTIBAND HF ANTENNA USING A FREE OPEN SOURCE SOFTWARE PLATFORM (4NEC2)
- THIS DESIGNED ANTENNA WILL BE FABRICATED AND CONFIRMED USING A VECTOR NETWORK ANALYZER & SOFTWARE DEFINED RADIO WHICH WILL BE RAN ON A LAPTOP.
- D1 DELIVERABLES: VIDEO DEMOS

PROBLEM STATEMENT

- Currently, TX State University does not have antenna modeling capability built into their EE course work. Students receive detailed instruction, but there is no design simulation environment to learn how to simulate and experiment with electromagnetic radiation patterns with regard to antennas.

- EE3340, EE3370, EE4370

PROBLEM SOLUTION

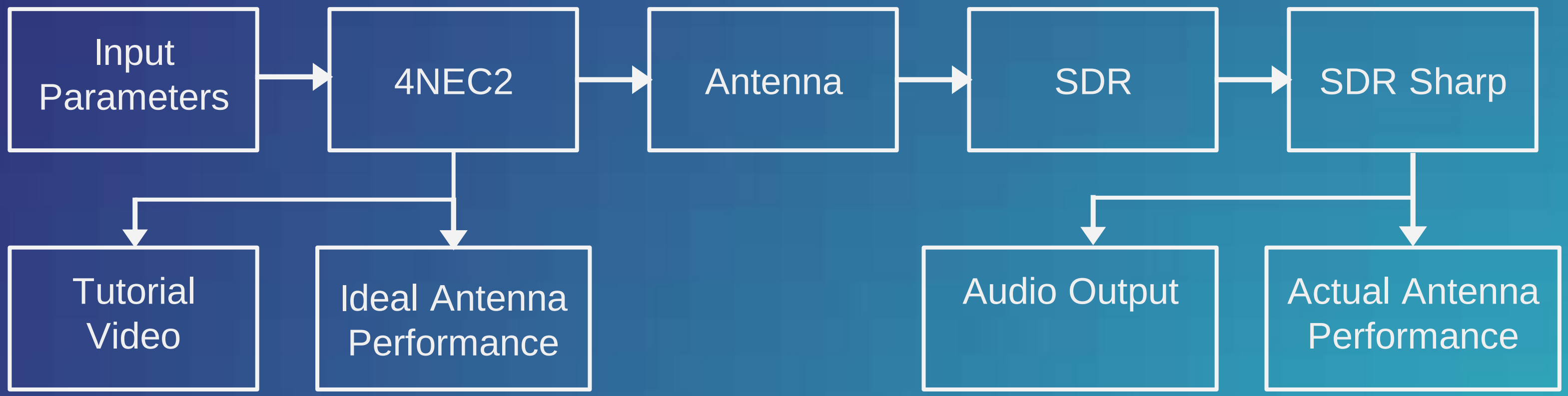
- Our team will use open source software (4NEC2) to design, fabricate, and confirm reception on HF bands in order to bring up 4NEC2 capability at TX State University.

- A short tutorial will be produced to walk future students through the simulation of a half wave dipole antenna.

PROJECT GOALS

- Design and simulate an HF antenna capable of receiving specified frequencies.
- Fabricate a multi-band dipole antenna to receive HF signals in the 10-40m (7.5-30MHz) range on the HAM bands.
- Use affordable SDR to receive HF signals for the purpose of antenna confirmation.
- Use VNA to confirm antenna characteristics match design thereby bringing up 4NEC2 capability.

GENERAL BLOCK DIAGRAM



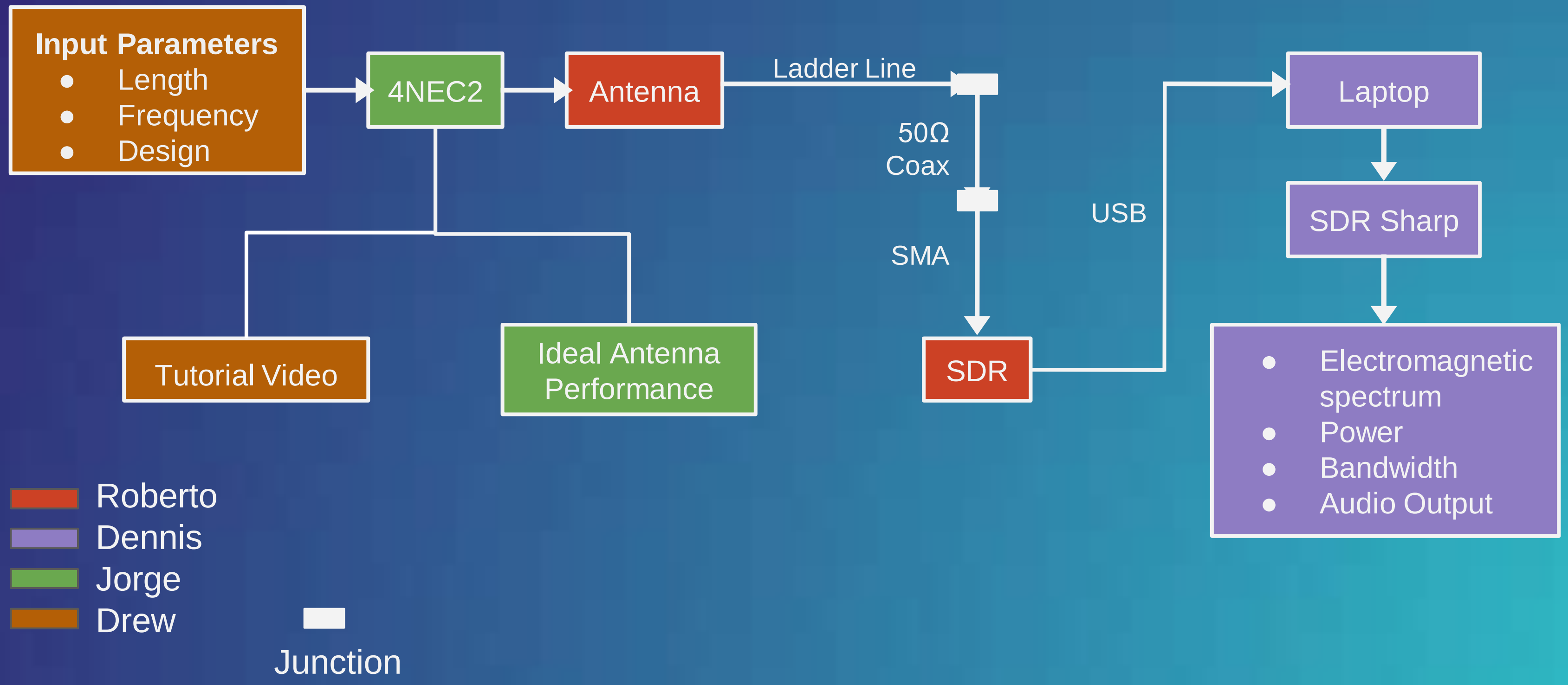
ROLES & RESPONSIBILITIES

Function	*Deliverables*	*DRI*
Simulate Antenna	Geometry, Impedance, Radiation Pattern	Jorge
	SWR, Smith Charts	Drew
Setup/Confirm SDR	SDR Software Setup, HF Unlock, Software Operation	Dennis
	HF Operation Confirmation	Roberto
HF Antenna Setup and Characterization	Materials, Fabrication and Assembly	Roberto

PROJECT DELIVERABLES

Deliverable	***DRI***
SDR HF Capability	Dennis
Half-Wave Dipole Antenna Simulation	Jorge
4NEC2 Instructional Video	Drew
G5RV HF Verification	Roberto
SDR Receiving HF Demo Video	Dennis
Ladder Line Length	Jorge
Design Antenna Simulation	Drew
Assembled Designed Antenna	Roberto

DETAILED BLOCK DIAGRAM



4NEC2 MILESTONES

Milestone	***Start Date***	***End Date***
Simulation of a simple half-wave dipole antenna in order to establish well known values for the geometry tested	10-23-2020	10-30-2020
Correctly modeling a designed antenna with values close to similar antenna models.	10-30-2020	11-15-2020
Improving efficiency of designed antenna through the modification of the 4NEC2 code.	11-27-2020	

SDR MILESTONES

Milestone	***Start Date***	***End Date***
Initial setup and VHF antenna setup to acquire a clear signal over air band. This verifies the operation of the SDR unit.	11-05-2020	11-16-2020
Connect a G5RV antenna to the SDR to attempt to acquire a clear HF signal. This verifies HF capability.	11-06-2020	11-08-2020
Make video demo RTL-SDR receiving HF with a simple longwire antenna.	11-27-2020	12-02-2020

Functional Spec Review

ERROR HANDLING

- Drop of electromagnetic spectrum in SDR Sharp
  - Check Connections
  - Power cycle SDR
- 4NEC2 output data is not as expected
  - Auto Segmentation
  - Correct Frequency
  - Feedpoint location

SAFETY & SECURITY

- No security required due to user not needing to submit any personal information to use this product.

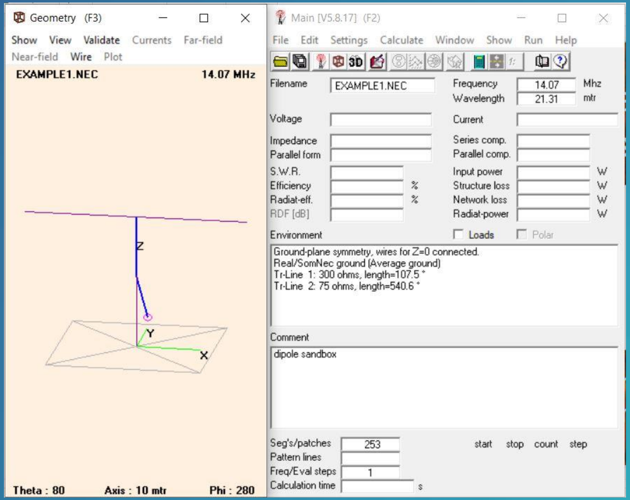
- User checks the wires for damage/debris/moisture and check if the antenna is grounded.

- User should not go near the antenna during thunderstorm.

SDR & 4NEC2 User interface

- SDR Sharp is open source software which will interface with SDR-RTL to receive an HF signal.
- 4NEC2 is open source software which has a user interface for antenna design.

SDR User Interface



4NEC2 User Interface

SOFTWARE PLATFORM & INTERFACE

Software	***Function***
SDR Sharp	Interfacing laptop->SDR module->antenna
4NEC2	To model and simulate the antenna & output designed characteristics for testing.

HARDWARE INTERFACE

Hardware	***Function***
SDR-RTL USB Dongle	The SDRSharp software subsystem needs the SDR/USB dongle to laptop.
SDR-RTL SMA	The SDR-RTL USB-> SMA Cable-> Coaxial Cable-> Ladder Line-> Antenna Feedpoint.

BOUNDARY CONDITIONS & CONSTRAINTS

Parameter	***Min***	***Max***	***Comments:***
Wire Length	5m	25m	Depends on final antenna length (½ Lambda)
Frequency	7.5MHz	30MHz	Based on 20m to 40m wavelength getting best SWR
Ladder Line Impedance	300Ω	450Ω	Better impedance match with 50Ω coax
Height Above Ground	15ft	50ft	To receive optimal signal
Ground	Real	Free Space	Terrain dependent
Beamwidth	68	88	Optimize half power
S11	-20dB	-10dB	Power Reflected from antenna
VSWR	1.2:1	1.93:1	Efficiency of Power Transmission

AMATUER RADIO BAND PERFORMANCE

BAND	Min(MHz)	Max(MHz)	VSWR	Impedance
10m	28	29.7	<2:1	73+RxΩ
12m	24.89	24.99	<5:1	78+RxΩ
15m	21	21.45	<5:1	78+RxΩ
17m	18.068	18.168	<5:1	78+RxΩ
20m	14	14.35	<2:1	70Ω
30m	10.1	10.15	<5:1	78+RxΩ
40m	7.0	7.3	<2:1	70Ω

EXPANDABILITY

The physical antenna is modeled and constructed according to the software design. The hardware is expandable.

Expandability of project:

- Frequency
- Arrays
- Power Source (transmitting)
- Transmit/Receive

The software is NOT expandable.

SERVICE, SUPPORT, & MAINTENANCE

1. The dipole antenna does not require service, support, or maintenance once it is installed.

1. On the software side of the antenna the user needs to go to the SDR and 4NEC2 websites for software updates.

PERFORMANCE

System	*Description*	*How Tested*
4NEC2	Software used to determine the ideal output of the antenna we designed.	Simulate a simple half wave dipole to see if the results obtained match the textbook values
Antenna	The physical hardware components connected to obtain the results ran in 4NEC2	Fabricate/construct half wave dipole. Use VNA to characterize antenna and compare to 4NEC2 Output.
SDR	Receives signals from antenna and converts/displays the signals on a laptop for the team to analyze	Receive VHF with the antenna included with the SDR then use G5RV to confirm HF reception.

CHALLENGES & CONCERNS

- Decide what HF bands the antenna will match with 4NEC2.
- Match component parameters for resonance
- Antenna fails to match 4NEC2 simulation output.
- Weather, ionosphere, and solar conditions can affect ability to receive HF signals.

PROJECT PROGRESS

Subsystem	***Progress***	***D1 Goal***
4NEC2	Simulated simple half wave dipole and antenna	4NEC2 Video demo
4NEC2	Simulated antenna design	Determine parts needed
SDR	Verify HF capability	Receive HF on SDR
SDR	HF capability unlocked	SDR Video demo

FUTURE TASKS

Subsystem	***Task***
4NEC2	Test and debug the design antena, verify the code with the design antena.
SDR	Order materials , Construct the design antena , verify/ test of design antenna

REFERENCES

- RTL SDR Sharp users guide at

  SDRSharp Users Guide

- Antennas propagation end fed wire at

  Propagation End fed wire

- 4NEC2 Users Guide at

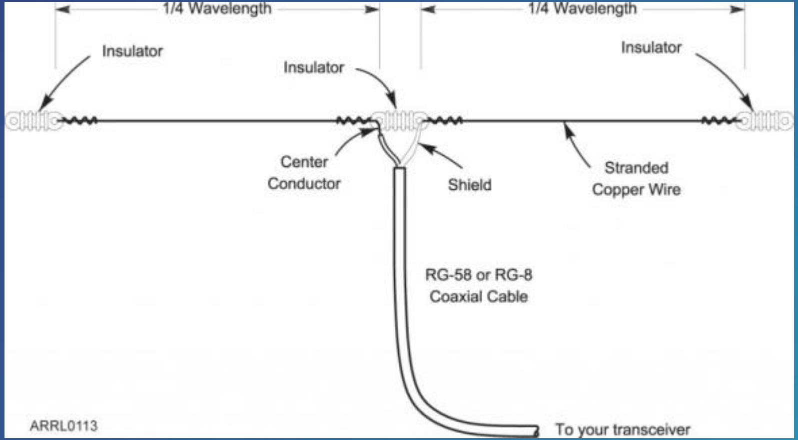
  NEC Manual

- Dipole and Longwire antenna guide

  73 Dipole and Longwire Antennas

QUESTIONS?

Thank You.



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E1.02-Using 4NEC2 Numerical Electromagnetic Code for HF Antenna Design

Product Specification

Roberto Colon, Project Manager

Jorge Blanco

Dennis Liao

Drew Schmidt

Sponsored by:

Texas State University

Bruce and Gloria Ingram Hall, West Woods St.

San Marcos, TX 78666

Date: November 11, 2020

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Revision History			
Version	**Date**	**Description**	**Author**
0.1	10/21/20	Sections Assigned	Roberto
0.5	10/28/20	Preliminary content for most sections	Roberto
0.6	11/08/20	Initial Review	Roberto
0.7	11/22/2020	Draft Submitted	Roberto
0.8	11/25/2020	Final Draft Submitted for Review	Roberto
1.0	11/30/2020	Final Draft Signed	Roberto

Table of Contents

1 Introduction

Created by: Drew Schmidt

Our project is to use Numerical Electromagnetic Code (4NEC2) antenna simulation software to design and test a High Frequency (HF) antenna. Our project will involve the design, simulation, fabrication, and verification of an HF antenna which will be set up at the Project Sponsor's workshop. The antenna will be capable of receiving narrow bandwidths of multiple HF frequencies ranging from 7.5-30MHz (10-40 Meter Wavelengths) and will rely on the use of free modeling software and a laptop running Software Defined Radio (SDR).

Another goal of our project is to produce a tutorial video on how to use the 4NEC2 software. This tutorial video is a major goal in our project because it will be incorporated in the curriculum of several Electrical Engineering courses for Texas State University including EE 3340, EE 3370, and EE 4370. This project will facilitate the simulation of electromagnetic structures by future Texas State University students at no cost.

1.1 Customer Requirements

Created by: Roberto Colon

The requirement is that the team design, simulate, and fabricate an HF antenna to use with a commercially available USB-SDR-HF receiver, to be designed using 4NEC2 open source numerical electromagnetic modeling software. The antenna must be able to receive on the 10-40 meter (7-30 MHz) HAM bands with focus on receiving the 20m band with the best efficiency. The goal of this project is to verify a designed antenna using the software, thereby proving that it works so that we can produce a short tutorial for future TX State Engineering students which will show how to model a simple dipole antenna using electromagnetic modeling software that is free.

1.2 Existing System

Created by: Jorge Blanco

Currently, there is no existing system at Texas State University that allows students to simulate electromagnetic structures at no cost.

Exposing future students to the 4NEC2 software could greatly enhance their understanding in electromagnetics by being able to implement designs and verify them using the new software.

1.3 Terminology

Created by Dennis Liao

Term	**Description**
4NEC2	Numerical Electromagnetic Code Software
D1/D2	Abbreviations for Design1 and Design2 courses at TX State
FCC	Federal Communications Commission
HF	High Frequency Band (3-30MHz)
HAM	Slang term for Amateur Radio
SDR	Software Defined Radio
SMA Cable	SubMiniature Version A Cable
SWR	Standing Wave Ratio
UHF	Ultra High Frequency
VHF	Very High Frequency

2 Functional Description

2.1 User Attributes and Use Cases

Created by: Drew Schmidt

2.1.1 Building a ½ Wave Dipole Free Space Antenna in 4NEC2

Step 1 Open 4NEC2 application. Please note that users must have a Windows operating system installed on their computer since the software is not compatible with Mac operating systems.

Step 2 Go to “Settings” then “NEC editor (new)”.

Step 3 Go to “Edit” then “input (.nec) file” a new user interface should appear.

Step 4 In the new interface click “Symbols” then in the bottom left make sure “Meters” is selected. (This ensures the geometric units of the antenna are in meters.)

Step 5 Go to “Geometry”

- In the first row under type select “wire”.
- Under “tag” enter an appropriate number (name) for the wire.
- Under “segments” select an odd number of segments for the wire. (The number must be odd to ensure the feed point is in the middle of the wire.)
- In the next six columns enter the 3 dimensional components of each end of your wire. It is recommended that you draw your design out on paper first so you have an understanding of where your wire is physically.
- Finally under radius enter the radius of your wire in meters.

Step 6 Go to “Source/Load”

- Under “Source” select “Voltage-src”
- Under “Tag” the wire tag number.
- Under “Real” enter your real voltage value

Step 7 Go to “Frequency/Ground” Make sure “Free Space” is selected under the ground drop down bar. Also enter the optimal frequency value you will be operating at.

Your Half Wave Dipole in Free Space is now complete. When exiting out of the editor interface a new interface will appear showing your antenna referenced to a 3 dimensional axis.

2.1.2 Frequency Sweep, 3-D Field Pattern, & Smith Charts in 4NEC2

Step 1 After designing your antenna go to the main user interface then click the “Calculator” drop down and select “NEC Output data”

Step 2 Select “Frequency Sweep” then input the start, stop, and step frequencies for your antenna. The input values will be in megahertz. Also select the “3D/Full” option. After values are entered click “Generate”

Step 3 Two new interfaces will appear. One shows SWR (Standing Wave Ratio) and impedance over the frequency sweep specified. The other interface will show multiple graphs of a 2D gain pattern around your antenna. To see the radiation field around your antenna go back to the main interface and select the “3D Field” button near the top. A new interface will appear.

Step 4 In the new interface you will see three drop down arrows on the right side. Select the middle drop down arrow and select “Pattern”. Then select the bottom drop down arrow and select “Tot-Gain”. You now have the 3D radiation field pattern.

Step 5 In the main interface select the “3D Viewer” button. This will display a new window that is the Smith Chart.

Figures 2.1A and 2.1B show the 3D radiation pattern and Smith chart for the same antenna.

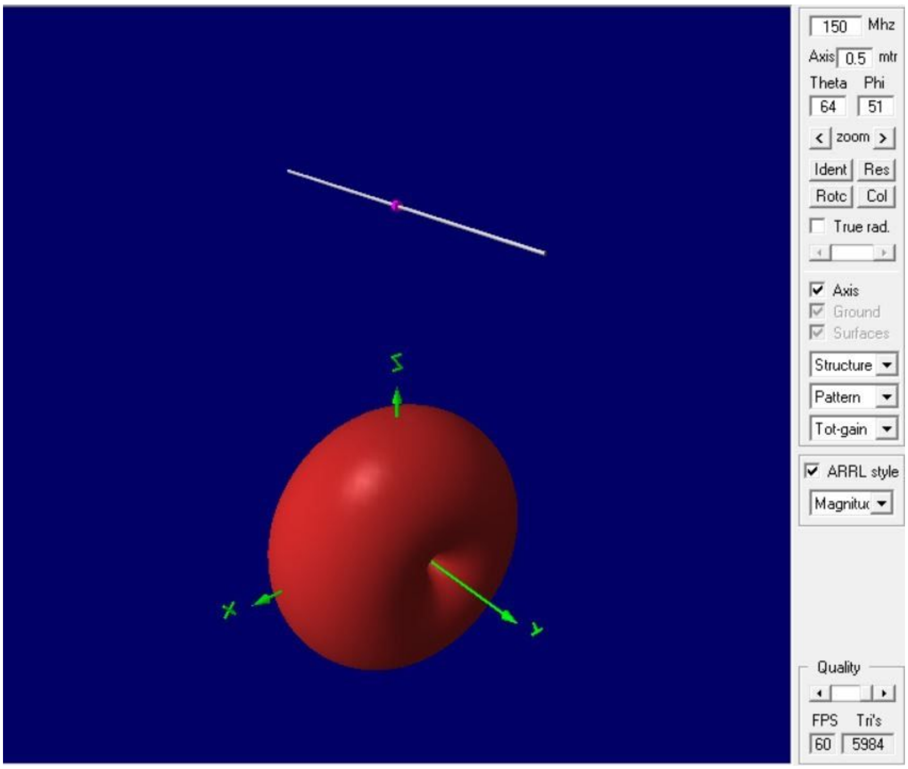

Figure 2.1A: 3D Radiation Pattern

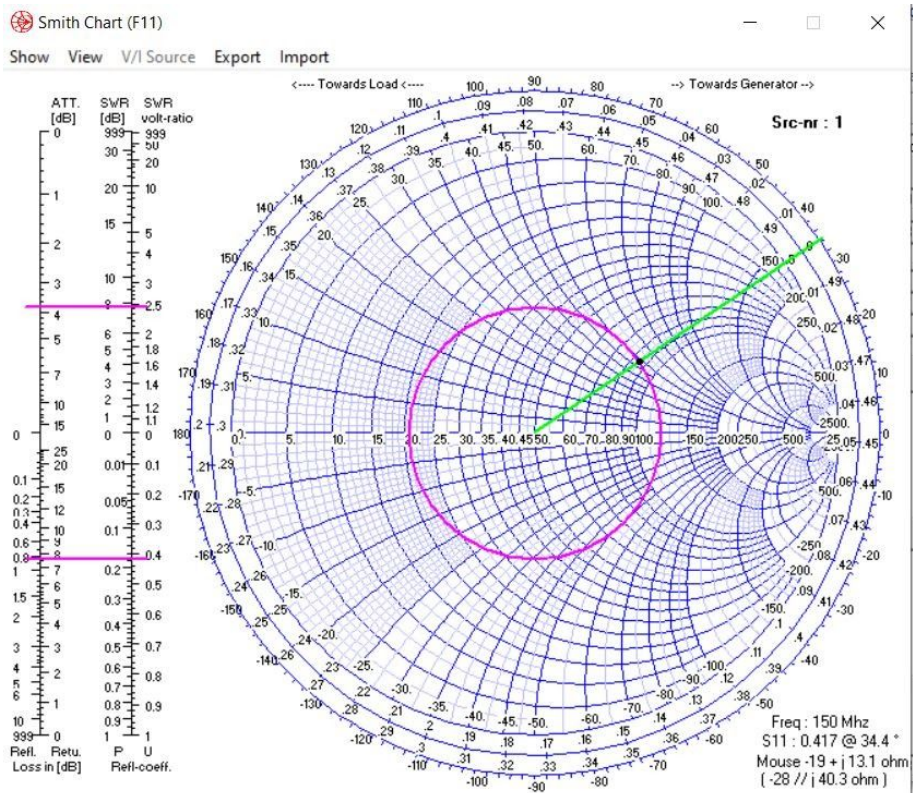

Figure 2.1B: Smith Chart

2.1.3 Using SDR to Receive an HF Signal

Created by Dennis Liao

Step 1 : Locate the sdrsharp-x86 folder if the user does not have this folder please download the software at https://airspy.com/download/. Please note that SDRSharp software is only compatible with X86 and Windows. If a user has a Mac, Linux, or ARM computer/laptop, then the user cannot use this software.
Step 2: Open the SDRSharp Application
Step 3: Plug in the dongle into the user computer or laptop USB port if a user has no USB port on their computer or laptop then the user needs to purchase a dongle for their machine to support USB, the product does not come with this adapter.
Step 4: Connect the SMA cable into the SDR module (the other end of the SMA should be connected to your antenna assembly).
Step 5: Locate the drop menu called Source: AIRSPY and then in the drop menu select the option of RTL- SDR(USB) .
Step 6: Then find the setting icon and click on it change the sample rate to 2.048MSPS and change the sampling mode from default sample to Direct sampling(Q branch)
Step 7: Press the play and tune button to 500k - 28.8Mhz and listen for antenna reception of HF signals. The RTL-SDR kit also comes with VHF antennas capable of picking up VHF/UHF transmissions.

2.2 Administration Functions

Created by: Roberto Colon

This system will be administered independently, that is, the software for both 4NEC2 and SDR radio are free open source software suites designed to be downloaded freely from the internet. This requires no admin to oversee the acquisition, use, or transfer of the software.

There are no functions specific to an administrator. The software is given freely to the user to set up and run how they require it within the software's designed specs.

The user is responsible for securing their software via security parameters on their machine.

2.3 Error Handling

Created by: Roberto Colon

In the event of internet connection loss, the user must go through their established protocols to reestablish connection to the internet. Neither 4NEC2 or SDR requires internet connection as the software, once installed, runs on the users system with no need for internet connectivity.

In the event of a connection loss between the SDR and the laptop, the user must begin to troubleshoot the connection between the USB connection and the computer. The user should take care to properly exit the software by shutting down SDR Sharp and then safely remove the drive from the computer via the menu option. The user should then attempt to remove the USB from the dock and then reconnect the drive and open SDR Sharp. Once SDR Sharp is open, the user must enter the devices menu and select the SDR USB device as outlined in section 2.1.3, step 5.

If there is a loss of connection between the antenna and the SDR, the user will see a drop in electromagnetic spectrum in SDR sharp. The user needs to troubleshoot all connections working their way from the USB out to the antenna via the following steps.

1) Check the connection between the SMA cable and the USB drive visually and physically. The SMA should be firmly seated and evenly screwed into the USB drive for best connectivity.
2) Once connection between SMA and USB is confirmed, move upline and inspect the SMA to coaxial cable connection. Visually and physically inspect the connection. Disconnect and ensure connection is clear of debris and moisture then reconnect.
3) Repeat step number two for the Coaxial cable to Ladder line connection. The connection should be clear of moisture and debris and then tightened securely once finished.
4) After steps 1-3 return to the console and restart SDR Sharp to check for connectivity. If connectivity is established, the troubleshooting is completed. If connectivity between antenna and the SDR is still not established, then the antenna must be lowered to check the final connection between the ladder line and the Dipole wire. Conduct the inspection as in step 2 and then return to the console to check for connectivity. If at this point connectivity is not established, then the issue is not the antenna and troubleshooting of the software itself must be conducted.

Battery Low

The system requires no external power and is run on the user's computer.

Storage Media Not Found

Any files saved in 4NEC2 are saved by the user on the machine chosen by them. If a file is not found, the user must reference their system troubleshooting process in order to locate the saved files. 4NEC2 will save output files in the system's local drive > 4nec2 > out.

Storage Media Full

There is no storage required to run the software. Storage for any 4NEC files is on the user's machine or an external drive chosen by the user. If there are storage issues with any of these systems, refer to the user manual for the chosen system in order to troubleshoot.

2.4 Safety and Security

Created by Dennis Liao:

The user will need to check the coaxial cables and SMA cables for wear and tear . The user should replace the damaged cables as exposed wire is a safety hazard. The user should not attempt to adjust the dipole antenna during severe weather conditions or inclement weather as the dipole can attract lighting. The user can not store any personal information to use this product and data will not be encrypted since it is not sensitive information as the user is using the product to receive unencrypted HF radio signals. The project does not have any significant security issues as this product is for recreation use for the purpose of listening to HF radio signals.

2.5 Help and User Documentation

Created by: Jorge Blanco

The user will be given a quick start guide on how to use SDR Sharp and how to receive an HF radio signal on SDR sharp. The set up of the dipole antenna will come with a reference guide on how to erect the antenna in its provided form.

For future use of the 4NEC2 software, users will have access to the User Manual that outlines structure guidelines, program inputs, outputs, and error messages. Along with the manual, a tutorial video highlighting essential features of the program will be provided to help give a good foundation on how to start using the program.

2.6 *Interfaces*

2.6.1 User

Created by: Drew Schmidt

2.6.1.A 4NEC2

First download the free software from https://www.qsl.net/4nec2/ and open the setup file. The software will begin to install on your computer. Once 4NEC2 is downloaded open the app and begin to design your antenna. Steps on how to use the software are above in section 2.1. Figure 2.6.1A below shows where the software can be downloaded from.

Figure 2.6.1A: 4NEC2 Download

The system is operating correctly if the software does not give any errors. Once the output data is obtained from 4NEC2 then it can be used to either compare the hardware results to or optimize the components of the antenna.

2.6.1.B SDR

The SDR is a model RTL-SDR made by a company called 'RTL-SDR Blog' and sold for $35 on Amazon as a kit which includes a set of small dipole antennas and the SMA cable. It is a small USB sized dongle that is a USB connection on one side for output to the computer, and SMA connector on the opposing side for input from the antenna. A picture is included below for reference. In order to use the SDR, the user must download the required software and then connect the USB to the laptop while the other end of the USB is connected via the SMA cable to an operable antenna. The software use is outlined in section (2.1.3) to include initial setup and basic system use.

Figure 2.6.1B: RTL-SDR Dongle with SMA/USB connections on each side

2.6.2 Software

Created by: Jorge Blanco

The 4NEC2 software is able to take user geometry inputs through the geometry editor and convert that into NEC code. This code can also be created and edited through a text file or the NEC editor to easily adjust the user inputs. User inputs can be wire length, wire impedance, ground type, voltage source parameters, etc. Once the code is ready, the user can run several tests to find outputs such as radiation pattern, frequency sweeps, antenna efficiency, impedance, SWR, and Smith charts. These can then be used to tune the antenna design and compare values to the hardware design.

The SDR Sharp software interfaces directly with the hardware. It takes data from the physical antenna from an SMA cable connected directly to the SDR USB dongle.

2.6.3 Hardware

Created by: Dennis Laio

The antenna components make up the hardware. Different antennas may be connected to the SDR via the SMA cable. In addition to the antenna, different transmission lines may be incorporated into different antenna designs thus making the hardware modular.

2.6.4 Mechanical

Created by Roberto Colon

The mechanical components of this system are limited to the construction of the antenna whether it be fixed or field expedient. The antenna system mainly consists of a series of wires connected by screw connectors and supported either by a mast or by securing with cordage to a solid structure. If made to be field expedient, the user can incorporate pulleys and weights, but the field expedient version of this hardware is not offered by this project.

2.7 Boundary Conditions and Constraints

Created by Roberto Colon

Constraints

1. The antenna dipole needs to be 15 feet above the ground.
2. The antenna needs to be in an open area that has a 60 ft width if possible for best reception.
3. The area where the antenna is deployed must be clear of any object(s) that can interfere with the antenna dipole's ability to receive a signal.
4. The antenna can only receive HF signals. If the user wants to transmit HF radio signals then the user needs to acquire an FCC radio license and must ground the antenna safely as it will emanate power proportional to the output power of the transceiver being used to transmit.
5. The condition of the ionosphere also plays a role in receiving the electromagnetic signals in the HF frequency band. The ionosphere is influenced by weather conditions and solar activity. Solar cycles have been proven to be historical and can be accounted for by researching when the best conditions take place with respect to geography and solar cycles.
6. A computer with internet access is required to download the free simulation software but once the program is installed internet access is no longer required to run either of the software suites.
7. Soil permeability will affect the signal being transmitted/received. This depends on the location of the antenna as well as the weather.
8. Users must have a computer or laptop that has a Windows operating system installed.

2.7.1 Performance

Created by: Dennis Laio

Software

Our design in 4NEC2 will require a few characteristics of our antenna to be specified before going into the performance parameters. These characteristics are listed below.

1. Our antenna geometry will be a grounded half wave dipole.
2. The feed point of the antenna will be in the center of the dipole.
3. The ladder line used will be between 300 and 450 ohms depending on our 4NEC2 simulations.
4. A 50 ohm coax cable will run from the ladder line to the SDR.
5. The height of our antenna will be 15 feet from the ground.

Table 2.8A demonstrates the minimum and maximum limits for each parameter of our design.

Parameter	Min	Max	Comments
Antenna Length	5m	20m	Depends on final antenna length (½ Lambda)
Frequency	7.5MHz	30MHz	Based on 10m to 40m signal wavelength. **Priority is the 20m band
Soil Permeability Coefficient	10^{-9}	10^{2}	This scale is based on clean gravel being a max and impervious soils being minimum
SWR	1.22:1	1.93:1	Efficiency of power transmission

Table 2.8A: Parameter limits

Hardware Performance Parameters					
Parameter	**Test Conditions**	**Min**	**Max**	**Units**	**How Tested**
Ladder Line impedance	Simulation and Realized at Site	300	400	ohms	Measure the end of the cable with a voltmeter.Characterize with VNA.
Reflection coefficient (S11)	Simulation and Realized at Site	-20	-10	dB	Simulation: Bandwidth will be the range where S11 is < -10dB. Confirm with VNA
Frequency	Receive a HAM frequency signal	10	40	Meters	Receive with SDR sharp to observe the ham band frequency being received.
Radiation pattern	Simulation Only	1	1.5	MHz	Sweep input frequency to create magnitude vs. frequency plot
BeamWidth	Simulation	68	88	Degrees	Optimize Half Power
Ham Band	VSWR range of ratio by simulation and with VNA	1.22:1	1.93:1	Unitless Ratio	Use the VNA to perform sweep.

Table 2.8B: Hardware Performance Parameters for Antenna Design.

Software Performance Parameters		
Function	**Description**	**How Tested**
New releases	When a new/updated version or release of the software is released, the user should be notified.	Construct an updated version and verify that notification correctly occurs.
User interface	Loads in 5 seconds or less	Use a timer to measure load time
Memory usage	The amount of Operating System memory occupied by the application. Target is 10MB, limit is 20MB.	Observations done from the performance log during testing.
System reliability	The reliability that the system gives the right result.	Measurements obtained from 100 different usage instances during testing. Software tested using test procedures outlined.
Title bars	Accurate and consistent titles will be displayed in all windows, frames, and dialogs	Each instance checked for accuracy and consistency
Dialogs	The user will be able to cancel all dialogs by hitting the [Esc] key	All dialogs tested by [Esc]
Access control	(a) If enabled, all users will be limited by their group assignments (b) If disabled, all users have free access to system resources	Check access with control both enabled and disabled
Platforms	The system will run on the following computer platforms: (a) Windows 10 (b) Windows 7	Test all functions listed above on all platforms

Table 2.8C: Software Performance Parameters

2.7.2 Software Platforms

Created by: Drew Schmidt

4NEC2

4NEC2 is an open source software which can be found at https://www.qsl.net/4nec2/ and is only available on windows. For a visual reference on where to download the software refer back to figure 2.6.1A. Once the file is downloaded just run the setup file and the program will begin to install. For use, refer to section 2.1.1 & 2.1.2.

SDR Sharp

SDR Sharp is a free open source software platform which allows a user to receive and modulate radio frequencies for the purposes of recreational listening. The software is able to process and receive a range of frequency bands when combined with a compatible SDR device such as the RTL-SDR USB device used with this project. The software can be downloaded from SDRSharp along with installation instructions for Windows 10, which cover the first run as well as a user guide to using the software.

2.8 Service, Support, & Maintenance

Created by: Drew Schmidt

The dipole antenna does not require service or support once it is installed. On the software side of the antenna the user needs to go to the SDR and 4NEC2 websites for software updates.The dipole antenna is designed to be fixed 15 ft above ground and the user is not expected to do maintenance on the antenna with the exception of

2.9 Expandability and Customization

Created by: Jorge Blanco

Users have several options when it comes to customization on the software side. Parameters such as geometry, length, wire impedance, and location of the antenna can all be adjusted for any simulation. Insulators can be placed at different points along the antenna, changing the frequency and allowing for better tuning. The voltage source applied to the structure can also be adjusted. Of course, these parameter changes will affect wavelength and impedance of the system.

When you download 4NEC2 from qsl.net/4nec2/, several folders of source code for different types of structures such as simple HF antennas all the way up to VHF multiband antennas are provided. This allows the user to select from a wide range of structures that allow modification of parameters in order to simulate their own designs.

Our project could be expandable if we had to meet different design requirements. For example, we could design an antenna for different frequencies. This could be done by changing wire lengths or the geometry. An element of transmitting signals rather than only receiving signals could also be added to our project. This would be done by adding a power source meant to transmit signals.

3 Project Alignment Matrix

Created By: Roberto Colon

Outside Advisors (if any) and affiliations:

No outside advisors have been consulted at this time. Our support consists solely of Texas State University professors.

TABLE 1: Knowledge Alignment Matrix

Course No.	Core knowledge	Specific knowledge incorporated by team
EE 3340 (Electromagnetics)	Design and analysis of transmission lines and electromagnetic structures.	Transmission line impedance, Smith Charts, VSWR
EE 3370 (Signals and Systems)	Frequency domain representation of signals frequency response, transfer functions. Block Diagrams.	View ideal receiving conditions over multiple frequencies. Create Block Diagrams
EE 4370 (Communications Systems)	Transmission of signals through linear systems, analog and digital modulation, and noise.	Model an optimal receiving system represented as an antenna

TABLE 2: Constraint Alignment Matrix (and applicable standards)

ABET Criterion 3 (c): "an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability."

Constraint Type	Specific Project Constraint
Economic	Cost Below $500
Environmental	Fixed position with minimum footprint
Health and safety	Safety Measures/ Proper Grounding
Social/Ethical	Obey FCC rules for HF Communication
Applicable Standards	ARRL Standards of conduct when communicating

4 References

Balanis, C. A. (2016). *Antenna theory: Analysis and design*. Hoboken, NJ: Wiley.

5 Approvals

The signatures of the people below indicate an understanding in the purpose and content of this document by those signing it. By signing this document, you indicate that you approve of the proposed project outlined in this Functional Specification and that the next steps may be taken to proceed with the project.

Approver Name	Title	Signature	Date
Roberto Colon	Project Manager		25NOV2020
Joshua Ready	D2 Project Manager		28NOV2020
Dr. Rich Compeau	Sponsor		30NOV2020
Dr. Karl Stephan	Faculty Advisor		30NOV2020
Prof. Mark Welker	Instructor		

Section	Author	Word Count
1.1,2.2,2.3,2.6.4,2.7,2.9,3	Roberto Colon	1,288
1.2,2.5,2.6.2,2.10	Jorge Blanco	482
1.3,2.1.3,2.4,2.6.3,2.8	Dennis Laio	968
1,2.1,2.6.1,2.8,2.9	Drew Schmidt	1,150

E1.02 - Using 4NEC2 Numerical Electromagnetic Code for HF Antenna Design

Project Plan

Roberto Colon, Project Manager

Jorge Blanco

Dennis Liao

Drew Schmidt

Sponsored by:

Texas State University

Bruce and Gloria Ingram Hall, West Woods St.

San Marcos, TX 78666

Date: October 21, 2020

Document Revision History Table		Template: 3/9/20
Version	Summary of Changes	Date
0.1	Section Owners assigned; draft Introduction added	10/07/20
0.2	Template info removed; the first draft of all sections completed	10/20/20
0.3	All sections updated during team review	10/21/20
0.4	Add the tables for the development costs	11/22/20
1.0	Final draft submitted for signatures	11/30/20

Contents

1 EXECUTIVE SUMMARY

The Executive Summary was written by Drew Schmidt.

High Frequency (HF) Band communications have been around for a long time and have a distinction from other Radio Frequency (RF) Bands. This distinction is that the HF band does not require the internet, satellites, or undersea/landlines to successfully transmit to a distant receiving station. Instead, the HF band relies on a layer of ionized air in the atmosphere to reflect the wave back toward the ground causing a series of reflections between the ground and ionosphere to allow the transmission to a receiving station that is over the horizon. HF band communications are important because the applications include use by governments, military, private organizations, and users in remote areas where HF may be the only form of communication.

The business impact this project provides is that Texas State gains a free, versatile, and accurate, antenna modeling software. The request is that our team use a software platform called 4NEC2 (Numerical Electromagnetic Code) to design an antenna for a specific application and then build, test, and verify said antenna design using the free software available and minimally priced parts.

Our project will involve the design, construction, and verification of an HF antenna which will be set up at the Project Sponsor’s workshop. The antenna will be capable of receiving a wide band of HF frequencies ranging from 7.5-30MHz (10-40 Meter Wavelengths) and will rely on the use of free modeling software and a laptop running Software Defined Radio (SDR) software. This project will improve the university's ability to model antenna designs through the production of a short instructional video which will walk future students through some of the intricacies of antenna modeling using the free software.

2 Product Block Diagram

The Product Block Diagram was written by Drew Schmidt.

The top-level diagram shown in figure 1 will represent our 4NEC2 software. The input for this system will consist of either a user or a text file that will fill out the parameters necessary to describe the antenna being modeled. The output will show data like the 3D radiation field pattern, Standing Wave Ratio (SWR), and the optimal angles that receive the most decibels.

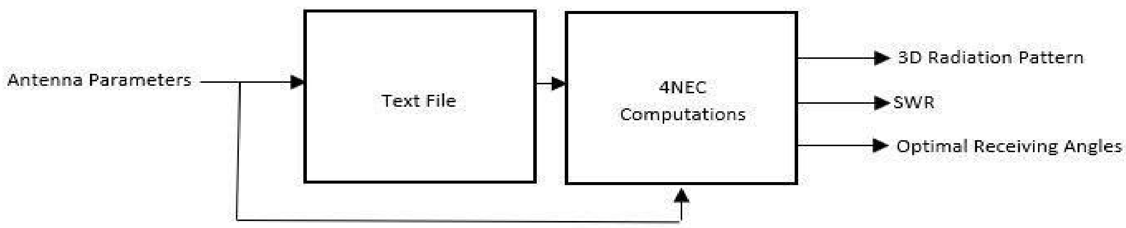

Figure 1: 4NEC2 Top-Level Block Diagram

The top-level diagram in figure 2 will represent the SDR and HF antenna. Our HF antenna will receive waves ten to forty meters long and will display the signal strength on a laptop while providing an output through the laptop speakers in order to hear the incoming radio traffic.

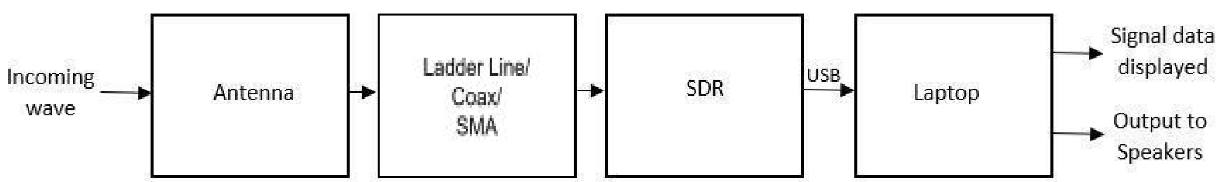

Figure 2: SDR Top-Level Block Diagram

2.1 4NEC2 Subsystem

The 4NEC2 Subsystem is owned by Drew Schmidt and Jorge Blanco.

The 4NEC software will require various input data from the user before returning any output information specific to how we model the antenna.

Input	Source	Description
Antenna Length	Incoming Wave	The antenna length will be an integer multiple of half the incoming wavelength (preferably odd integer multiple)
Frequency	Incoming Wave	We will receive frequencies between 7.5 and 30 megahertz
Ladder line impedance	Antenna feed point	The impedance will vary from 300 to 450 ohms (Length will be Adjusted for matching 70-73 Ohms)
Soil Permeability	Antenna Location	Input the type of terrain the antenna is located on

Table 1: 4NEC2 Inputs

Output	Destination	Description
SWR over frequency	4NEC Program	SWR over a frequency sweep
3D Far-Field Pattern	4NEC Program	Shows optimal receiving angles
Smith Chart	4NEC Program	Displays Antennas impedance

Table 2: 4NEC2 Outputs

4NEC2 Milestones	
Milestone	**Date**
Simulation of a simple half-wave dipole antenna in order to establish well-known values for the geometry test. This verifies that the 4NEC2 program works.	*10/23/20*
Correctly modeling a designed antenna with values close to similar antenna models. This verifies that our antenna code is correct or on the right path to being correct.	*11/15/20*
Improving the efficiency of our designed antenna through the modification of the 4NEC2 code which improves our antenna parameters. This verifies that the code is able to be modified correctly when given specific parameters to modulate.	*11/27/20*

Table 3: 4NEC2 Milestones

2.2 SDR Subsystem

The SDR Subsystem is owned by Roberto Colon and Dennis Liao

This system will receive the signal from our antenna via the ladder line and coax cable. From there the system processes the signal and outputs the data to a laptop via USB connection. To initially test the system we will connect it to the included antennas and attempt to acquire a VHF/UHF signal on the airband. Then we will test an existing antenna system called a G5RV Jr. to ensure that we have unlocked the HF capabilities of the SDR.

Parameter	Min	Max	Comments
Receive HF Signal	10m Wavelength	40m Wavelength	The antenna will capture energy from a radio wave that has propagated through the air.
Price	0	$500	We will use off the shelf parts that are easily attainable as well as test equipment which can be bought on the open market.
Antenna Length	2.5 meters	40 meters	The antenna length is a function of half the wavelength of the frequency or every odd multiple integer of a half wavelength.
Ladder Line	300 Ohm	450 Ohm	The ladder line impedance needs to be matched using our simulation to see which impedance will produce the greatest efficiency and at what length the ladder line needs to be trimmed to.
Coaxial Cable	50 Ohm	75 Ohm	The coax cable impedance needs to be matched to the antenna using our simulation to produce the greatest efficiency over our proposed frequency range.

Table 4: SDR Parameters

Input	Source	Description
Antenna	Incoming Wave	The antenna will capture energy from a radio wave that has propagated through the air.
Frequency	Incoming Wave	We will be receiving frequencies between 7.5 and 30 megahertz.
Ladder line impedance	Antenna feed point	The impedance will vary from 300 to 450 ohms with the goal of having a strictly real impedance with no reflection in the ladder line matched to 70-73 Ohms.
Coaxial Cable	Ladder Line	Will transfer energy via coax to theSMA & SDR USB dongle.

Table 5: SDR inputs

SDR Milestones	
Milestone	**Date**
Initial setup and unlock of HF capability in SDRSharp Software. This enables users to receive HF signals on SDR.	10/20/20
VHF antenna connected to the SDR system to acquire a clear signal over the airband. This verifies the operation of the SDR unit and the software program to listen to radio traffic.	*11/16/20*
Connect a G5RV antenna to the SDR to attempt to acquire a clear HF signal. This test confirms that HF capability is unlocked for the SDR and that we can receive HD signals with a manufactured antenna.	*11/24/20*
Connect the designed antenna and receive signals within the desired frequency range. This test confirms the designed antenna is able to receive HF frequencies.	*1/24/21 (D2)*
Connect a VNA to the designed antenna to characterize the antenna and record VSWR, S11, and impedance. This test confirms that the antenna matches the designed parameters.	
Make video demo RTL-SDR receiving HF with a simple antenna	*11/27/20*

Table 6: SDR Milestones

3 Project Schedule

The Project Schedule section was written by Jorge Blanco

Please see attached PDF file.

4 Development Costs

The Development Costs section was written by Dennis Liao

4.1 Labor Categories and Burdened Hourly Cost Estimate.

The table below is the labor category that is necessary for the development of the antenna. Some of the labor categories are not needed for this project. Please refer to the **Justification** section of the table for more information.

Labor Categories Required	
Category	**Justification**
Digital Design Engineer	N/A because we do not need to use any circuits for digital systems.
Analog Design Engineer	N/A because we do not need to develop and modify circuits for analog systems. The antenna does not need circuits.
Software Engineer	Need write software for the 4NEC2 and SDR sharp
Test Engineer	Need to test the antenna design for efficiency, reflection coefficient, and SWR.
Technical Writer	Need to create quick reference guides to notify the user of how to receive the signal from the antenna. Need to create a user manual on how to use the 4NEC2 and SDR software.
Technician	To modify our antenna prototype.
Fabricator/Assembler	Need to assemble the HF antenna at the site selected.
Project Manager	To provide guidance and leadership on the project and make sure the project is completed on time.
People Manager/Supervisor/HR	N/A. A PM is already allocated and the team is too small for a dedicated HR team.
Consultants	To provide technical information when needed.
Contractors	To help install the final antenna design on to a fixed location above the ground and ensure local codes are adhered to since an antenna is being erected in a residential area.

Table 7: Required Labor Categories

The table below is the labor cost and burden rate that is needed to complete this project. The estimated salaries are based on the United States Department of Labor Bureau of Labor Statistics report for 2018-2019. Please note the burden rate and estimated salaries are subject to change based on a person's geography, which can affect the cost of living. The table below used the median estimated salary from the United States Department of Labor Bureau of Labor Statistics report for 2018-2019.

Labor Cost using estimated salary and Burden	**Burden Rate = 66%**			
Labor Category	**Hourly Salary**	**Burdened Cost and Hours**	**Hours Required**	**Labor Cost**
Digital Design Engineer	NA	NA	NA	NA
Analog Design Engineer	NA	NA	NA	NA
Software Engineer	$52	$104	150	13,000
Test Engineer	$29	$58	80	$6,960
Technical Writer	$37	$74	20	$2,220
Technician	$31	$62	20	$1,860
Fabricator and Assembler	$15	$30	20	$900
People Manager, Supervisor, HR	NA	NA	NA	NA
Consultants	$39	$78	104	$12,168
Contactors	$17	$34	20	$1,020
Project Manager	$49	$88	105	14,385
Total	$26,952	$528	519	$52,493

Table 8: Labor Costs

4.2 Material Costs – Non-Capital Expenditures

The table below represents the material costs required to complete this project. All the material cost information is in the reference section. We are planning to purchase the necessary materials from DXengineer, Amazon, Home Depot/Lowes, and Academy.

Material Costs - Non Capital Expenditures

Task	Materials	Cost	
Simulation	4NEC2	$0.00	
Fabrication of antenna	25' of 450 ohm Ladder Line	$18.75	
	Coaxial Cables 30ft	$0.00	Already supplied
	SMA cables	$0.00	Part of SDR Kit
	SMA to Coaxial Adapter	$8.00	
	Insulator Kit	$29.99	
	Antenna Wire 150'	$26.99	
Pulley system	Rope at 100ft	$12.29	
	Pulley block	$6.00	
Testing antenna	G5RV jr	$0.00	Already supplied
	VNA	$350.00	Approximate Cost (Modell Dependent)
	SDR Kit	$24.95	
		$476.97	Total

Table 9: Material Costs/Non-Capital Expenditures

4.3 Capital Expenditures

The table below outlines the allocated capital expenditure needed to accomplish this project. We used the average housing price from Zillow. The average housing price is the cost for us to place the antennas; Since the antenna needs to be in a fixed location, there is a need to calculate the property cost. To find the property's hourly cost we use the average monthly mortgage payment for a 30 year period and divide that payment by the number of days in a month. Then we divide the mortgage payment per day by 24 hours to get the hourly rates.

Allocated Capital Expenditure Estimate

Task	Equipment	Estimated Cost	Hourly Rate	Hour needed	Total Cost
Develop antenna	Land	$434,755	$2	200	$400
Test antenna	Yaesu FT-891 HF/50MHz All Mode Mobile Transceivers FT-891	$640	$3	50	$150
Test SDR	SHAKESPEARE–5226-XT 8' Galaxy VHF Antenna	$230	$2	50	$100
					$750

Table 10: Capital Expenditure estimate

4.4 Total Estimated Project Costs

Table 5 represents the total cost of completing this project. The biggest cost of the project is the cost of labor. The materials themselves are relatively cheap but require the skills of professional engineers to design and fabricate them to specs.

Total Cost

Expense	**Total Cost**
Labor	$52,493
Materials	$477
Capital Expense	$750
Total	$53,720

5 Test Procedures

The Test Procedures Section was written by Roberto Colon

The approach to testing is to use the 4NEC2 software to simulate the ideal case of the gain, SWR, S11, impedance, and radiation pattern of our designed antenna. Then we compare the 4NEC2 parameters to a GR5RV Jr. pattern to see how much of our antenna design is similar to the GR5V Jr. The network unit testing helps us determine how much signal is lost via the ladder line.

Test Plan Overview	
4NEC2 software Subsystem Unit Tests	**DRI**
1A. Using researched textbook values for Input impedance, radiation pattern, beam width, S11, and VSWR we will model an antenna and compare to 4NEC2 output to ensure the software produces values close to researched/known values under ideal conditions.	Jorge
1B. Model a G5RV Jr. half-wave dipole antenna and compare results to known values for impedance, radiation pattern, SWR, and reflection coefficient.	Drew
SDR Unit Test	**DRI**
2A. Software setup and connection of included VHF antenna to check if the SDR receives local airband. This will tell us if our SDR is functional on the VHF/UHF band initially.	Dennis
2B. Setup HF band of SDR and test with a G5RV Jr. antenna. The antenna test will confirm the SDR is working on the HF bands.	Roberto
Antenna Subsystem Unit Test	**DRI**
3A. Assemble antenna and connect to VNA to test reflection coefficient, impedance, and SWR.	Roberto
3B. Use the Smith chart along with measured VNA values and modeling software to make design improvements	Roberto
3C. Connect Antenna to Yaesu FT857D Transceiver to check the reception of the antenna and confirm the reception of signals in desired bandwidth.	Dennis
3D. Connect the antenna to SDR to see if it receives the same frequency as the test on the Yaesu FT857D.	Dennis
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Intentionally Blank	
Overall System Integration Tests	**DRI**
4A. Receive a clear signal from a select HF frequency band in SDR sharp above 10MHZ (20m Band Priority)	Roberto Colon
4B. Ability to receive Ham bands ranging from 10-40m	Jorge

Table 11: Test Plan

5.1 4NEC2 Software Subsystem Unit Tests

Test 1A		Written by: Jorge Blanco
Subsystem: Model a simple half wave dipole and test output accuracy of 4NEC2		Tested by: Drew/Jorge 11/27/2019
Equipment Required:	Windows Laptop and the 4NEC2 software	
Description: This test is to design and simulate a horizontal half wave dipole antenna in free space. 4NEC2 will provide outputs such as radiation pattern, impedance, SWR, and		
Overall Results: PASS / FAIL / Could not be complete		

#	Procedure	Expected Result	Actual Result	Comments:
1	Find length of dipole antenna for design target of 14.1 MHz (20m band).	5.06 meters	5.06 meters	PASSED: The length was found by using a wavelength formula, λ=C/L, where C is the speed of light.
2	Write code in the NEC editor to model the dipole in free space. Run the generate function for the original file. This will output impedance.	70Ω	69.6-j12Ω	PASSED: The real impedance was very close to the desired 70Ω. Although there was slight imaginary impedance, this design is still viable to represent a half wave dipole in free space.
3	Find the radiation pattern by using the generate function for a far field pattern.	Donut-shaped radiation pattern	Donut-shaped radiation pattern	PASSED: At 14.1MHz, the antenna produced the ideal radiation pattern. The most power is shown perpendicular to the antenna and there is no power at the ends of the antenna. This lines up with the ideal radiation pattern for the ideal half wave dipole.
4	Using the generate function, run a frequency sweet from 14.0MHz to 14.2MHz with a step of 0.1MHz. This will show the SWR and if the antenna is designed correctly for the target 20m band.	SWR<1.5	SWR=1.48	PASSED: The frequency sweep shows that the SWR was 1.48 at 14.1 MHz. It also shows that at 14.1Mhz, the SWR was lower than at any other frequency. This shows that the design is correct

				and optimized exactly for the 20m band (14.0MHz-14.35MHz).

Overall result = Passed

Notes/Comments: Under ideal conditions, this test confirmed that 4NEC2 yields the expected and known outputs for a half wave dipole in free space. This test is important to the user because it ensures that the dipole itself is being designed correctly by comparing and matching the simulated values to the known textbook values. Since this was the first test under the 4NEC2 subsystem, it was essential in moving forward in simulated more complex systems.

Test 1B		Written by: Drew
Subsystem: Model a manufactured antenna and test output accuracy of 4NEC2		Tested by: Drew/Jorge 11/27/2019
Equipment Required:	Windows Laptop and the 4NEC2 software	
Description: This test is to ensure the antenna we build will be optimal for receiving at 10, 20, and 40 meter bands. Simulating our antenna before building it will give us the exact dimensions of every component for our design.		
Overall Results: PASS / FAIL / **Could not be complete**		

#	Procedure	Expected Result	Actual Result	Comments:
1	Model our antenna design and debug the 4NEC2 code	Obtain an accurate model of our antenna with the necessary components.	We were able to model the antenna having a length of 10 meters, 450 ohm ladder line, and 50 ohm coax.	Passed. Originally we were running tests to determine the impedance of our ladder line. After consulting with our advisor we determined that 450 ohm ladder line is ideal for our antenna.
2	Run the code	Obtain Radiation pattern, SWR, and impedance results	Output data was received. Radiation pattern, SWR, and impedance over frequency was obtained.	Passed. after modifying the input file to accurately represent our antenna we were able to obtain the output data.
3	Look at the output for our antenna design and compare the G5RV radiation pattern and gain to our output radiation pattern and gain.	Have an SWR of less than 1.5 on the 20 meter band or 15 MHz.	SWR of 1.7 at 17.9 MHz.	Could not be complete. We need to optimize the length of our ladder line by maintaining load impedance of the antenna as we increase the length of our line.

Overall result = Could not be complete.

Notes/Comments: More testing is needed to find the optimal length of our ladder line. The load impedance of the antenna under ideal conditions must remain the same as we add ladder line. This will be done by running simulations for every foot of the ladder line we add then adjusting the length of our antenna to maintain the optimal load impedance at 15 megahertz.

5.2 SDR Subsystem Unit Tests

Test 2A	Written by: Dennis Liao
Subsystem: Antena kit receive HF signal	Tested by: Dennis Liao 10/26/2020
Equipment Required:	Windows Laptop, SDR-RTL USB, HF Antenna with USB/SMA Connectors
Description: This test is conducted to confirm that HF capability has been unlocked on our SDR-RTL USB radio dongle and that SDRSharp software can display the HF signal received by the simple dipole antenna that came with the kit.	
Overall Results: **PASS** / FAIL / Could not be complete	

#	Procedure	Expected Result	Actual Result	Comments:
1	Attach SDR-RTL USB dongle into laptop or computer USB port and then open SDRSharp application. Use the drop menu in the source menu and select RTL USB to configure SDR-RTL USB device	Device Detected, name shown	Device detected, name shown. The RTL -SDR (USB) name is not gray out.	PASSED: Software was able to register the presence of SDR USB. Device name is shown in the “SOURCE” window at the top of the options menu.
2	Open Configuration menu (Gear Icon) and setup HF Parameters by selecting the proper device in the ‘Device’ menu and select ‘Direct Sampling (Q branch)’ in the ‘Sampling Mode’ Menu. Do not change any RF gain setting as this will affect what signal the user can receive.	Device is read by populating name in ‘device’ window. user is able to select direct sampling	Device is read by populating name in ‘device’ window. user is able to select direct sampling	PASSED: Software was able to read the USB device and populate the name in the ‘Device’ window and Direct Sampling (Q-branch) was able to be selected thus enabling HF reception on SDR using SDRSharp software. Sampling rate of 2.4 MSPS was used.
3	Set up the simple dipole antenna in a satisfactory location with overhead clearance and off the ground. Connect antenna using UHF to SMA connector.	Clear HF signal received. Confirm by	Many HF channels received. Confirmed	PASSED: HF reception is confirmed using a HF simple dipole antenna that came with a kit and SDR. This confirms the operation of SDR,

	Connect SMA to USB-RTL dongle which is connected to laptop or computer running SDRSharp with steps 1&2 above completed. Tune SDRSharp tuner to any HF frequency from 3-40 MHz and listen for Amateur radio bands that produce HF signal.	listening for callsign and power, then lookup on the internet to confirm HF station broadcasting	3 stations by call sign and transmission power.	SDRSharp Software as well as the ability to receive HF signals using the combination of SDR-RTL dongle and SDRSharp application. The HF signal is displayed on the user screen.

Overall result = Passed

Notes/Comments: The user will receive a better HF signal if the simple dipole antenna that came with the antenna kit is 5 feet above the ground. The user should conduct this testing during the evening hours of the day to receive the maximum strength of a HF signal. The time of day can affect the strength of the HF signal . Also any object around the antena will affect the performance of the antena but this test was conducted with no object interface with the antenna ability to receive HF signal.

Test 2B		Written by: Roberto Colon
Subsystem: HF setup and Confirmation in SDRSharp		Tested by: Roberto Colon 10/26/2020
Equipment Required:	Windows Laptop, SDR-RTL USB, G5RV Jr. HF Antenna with USB/SMA Connectors	
Description: This test is conducted to confirm that HF capability has been unlocked on our SDR-RTL USB radio and that SDRSharp software can work in conjunction with the SDR to receive HF signals given a manufactured HF antenna not of our team's design.		
Overall Results: **PASS** / FAIL / Could not be complete		

#	Procedure	Expected Result	Actual Result	Comments:
1	Attach SDR-RTL USB to laptop and open SDRSharp. Setup parameters in SDRSharp to configure SDR-RTL USB device	Device Detected, name shown	Device detected, name shown.	PASSED: Software was able to register the presence of SDR USB. Device name is shown in the "SOURCE" window at the top of the options menu.
2	Open Configuration menu (Gear Icon) and setup HF Parameters by selecting the proper device in 'Device' menu and select 'Direct Sampling (Q branch)' in the 'Sampling Mode' Menu.	Device is read by populating name in 'device' window. user is able to select direct sampling	Device is read by populating name in 'device' window. user is able to select direct sampling	PASSED: Software was able to read the USB device and populate the name in the 'Device' window and Direct Sampling (Q-branch) was able to be selected thus enabling HF reception on SDR using SDRSharp software. Sampling rate of 2.4 MSPS was used.

3	Set up G5RV Jr. Antenna in a satisfactory location with overhead clearance and off the ground. Connect antenna using UHF to SMA connector. Connect SMA to USB-RTL dongle which is connected to laptop running SDRSharp with steps 1&2 above completed. Tune SDRSharp tuner to any HF frequency from 3-30 MHz and listen for Amateur radio/HF traffic.	Clear HF signal received. Confirm by listening for callsign and power, then lookup on the internet to confirm HF station broadcasting	Many HF channels received. Confirmed 3 stations by call sign and transmissi on power.	PASSED: HF reception is confirmed using a manufactured HF antenna and SDR. This confirms the operation of SDR, SDRSharp Software as well as the ability to receive HF signals using the combination of SDR-RTL and SDRSharp.

Overall result = Passed

Notes/Comments:

5.3 Antenna Subsystem Unit Test

Test 3A		Written by: Roberto Colon
Subsystem: Use VNA to characterize antenna and confirm design outputs of 4NEC2		Tested by: Roberto Colon, D2/(future date)
Equipment Required:	Designed Antenna, VNA, 4NEC output of antenna model parameters, laptop, SDR-RTL, all connectors for Ladder Line/coax/SMA.	
Description: This test is to characterize our designed antenna and confirm that the output model of 4NEC2 is a close description of our realized antenna design.		
Overall Results: Match / Not Matched / Could not be complete		

#	Procedure	Expected Result	Actual Result	Comments:
1	Test/Calibrate VNA per the user guide included with VNA using test connectors.	Calibration successful		
2	Connect the designed antenna via ladder line, coax, SMA to the VNA.	Antenna registers on VNA as connected		
3	Conduct antenna tests using VNA per user instructions.	Parameters of antenna output for S11, SWR, Impedance		
4	Compare results of VNA output with given parameters from 4NEC2 of antenna characteristics.	Match within 10% error		

Overall result =

Notes/Comments: Test will be conducted at a future time.

Test 3B		Written by: Roberto Colon
Subsystem: Make design improvements using Smith Chart and VNA outputs if possible.		Tested by: Roberto Colon, D2 (Future Date)
Equipment Required:	Designed antenna, VNA, Smith Chart, output parameters from 4NEC2, Characteristics of antenna from test 3A, laptop with reference material for adjustments, 4NEC2 software, SDR-RTL USB, SDRSharp	
Description: This test will be completed in order to adjust the antenna if required once test 3A is complete. The test will be dependent on the output of our VNA characterization and the margin of error that the antenna displays with respect to our design parameters from 4NEC2.		
Overall Results: Match / Not Matched / Could not be complete		

#	Procedure	Expected Result	Actual Result	Comments:
1	Take output of VNA test and compare with expected performance parameters output from 4NEC2.	Greater than 10% error if we are conducting this test		
2	If parameters are out of tolerance, use Smith chart readout from VNA to bring the antenna into desired error range or better. This is done by adjusting lengths of transmission lines or dipole.	Antenna characteristics are adjusted to within 10% or better of parameters given by 4NEC2.		
3	Conduct Test 3A again to get current performance parameters and repeat this test if necessary. If the antenna can not be brought to within parameters, a redesign may be required.	Within 10%		
4	Before conducting redesign, test VNA on G5RV Jr. to ensure the accuracy and proper operation of the machine.	Parameters match the specifications of the manufactured antenna		

Overall result =

Notes/Comments: Test will be conducted at a future time.

Test 3C		Written by: Dennis Liao
Subsystem: Connect Antenna to Yaesu FT857D Transceiver to check the reception of the antenna and confirm the reception of signals in desired bandwidth.		Tested by: Dennis Liao on a future date
Equipment Required:	Windows Laptop Or computer , RTL SDR USB dongle , SMA cables ,Coaxial cable , simple dipole antenna	
Description: This test is to confirm the antenna is receiving the correct bandwidth of the received signal.		
Overall Results: PASS / FAIL / Could not be complete		

#	Procedure	Expected Result	Actual Result	Comments:
1	Plug in the RTL SDR USB dongle into the user device USB port and then attach the SMA cable into the other end of the RTL SDR USB dongle and run SDR sharp software.	SDR sharp recognize the RTL SDR USB dongle	SDR sharp recognize the RTL SDR USB dongle	The application software recognizes the device and is ready for use.
2	Connect the Yaesu FT 857D transceiver cables into the antenna .	The transceiver power on and can output a signal	The transceiver power on and the antenna is ready for trassimission	The transceiver powers on and outputs a signal at a desired bandwidth.
3	Look at the output of the antenna on SDR Sharp and look at the output of the transmission the output bandwidth should be matched.	The antena receive a HF signal that match the transceiver output signal	The antena receive a HF signal that match the transceiver output signal	The SDR sharp displays the matching bandwidth of the signal as the output of the transceiver.

Overall result = Not complete since our final antenna has not been designed and deployed for testing.

Notes/Comments:

Test 3D		Written by: Dennis Liao
Subsystem: Connect the antenna to SDR to see if it receives the same frequency as the test on the Yaesu FT857D.		Tested by: Dennis Liao future date
Equipment Required:	Windows Laptop Or computer , RTL SDR USB dongle , SMA cables ,Coaxial cable , simple dipole antenna	
Description: This test is confirYaesu FT857D. m the simple dipole antenna receives the same frequency as the Yaesu FT857D.		
Overall Results: Match / No match / Could not be complete		

#	Procedure	Expected Result	Actual Result	Comments:
1	Plug in the RTL SDR USB dongle into the user device USB port and then attach the SMA cable into the other end of the RTL SDR USB dongle and run SDR sharp software.	SDR sharp recognize the RTL SDR USB dongle	SDR sharp recognize the RTL SDR USB dongle	The application software recognizes the device and is ready for use.
2	Connect the Yaesu FT 857D transceiver cables into the antenna .	The transceiver power on and can output a signal	The transceiver power on and the antenna is ready for trassimission	The Yaesu FT 857D transceiver is powered on and can be transmitted as a signal .
3	Look at the output of the antenna on SDR Sharp and look at the output of the transmission the output bandwidth should be matched.	The antena receive a HF signal with the desire frequency that match the transceiver output signal	The antena receive a HF signal that match the transceiver output signal	The antenna receives the match frequency signal from the transceiver.

Overall result = Not complete since our final antenna has not been designed and deployed for testing.

Notes/Comments:

5.4 Overall System Integration

Test 4A		Written by: Roberto Colon
Subsystem: Designed antenna HF reception with SDRSharp		Tested by: Roberto Colon D2 (Future Date)
Equipment Required:	Windows Laptop, SDR-RTL USB, SDRSharp, designed antenna with all cables and connectors	
Description: This test will confirm the designed antennas ability to receive an amateur radio band in the specified frequency range with the 20m band being the priority (the antenna will be 'tuned' to this frequency to begin with).		
Overall Results: PASS / FAIL / Could not be complete		

#	Procedure	Expected Result	Actual Result	Comments:
1	Connect designed antenna to SDR-RTL USB drive via cables/connectors and run SDRSharp	Antenna registers by displaying RF/IR waterfall patterns in the UI of SDRSharp.		
2	Tune the interface in SDRSharp to an HF band using appropriate parameters to include bandwidth, sideband, frequency, filter, and power level.	HF Traffic received 5x5		

Overall result =

Notes/Comments: Test to be conducted on a future date.

Test 4B		Written by: Jorge
Subsystem: 4NEC2 antenna design and simulation		Tested by: Drew/Jorge 11/27/2019
Equipment Required:	Windows Laptop and the 4NEC2 software	
Description: This test is to confirm that the design antenna being simulated is capable of receiving signal from the 10m-40m bands.		
Overall Results: **PASS** / FAIL / Could not be complete		

#	Procedure	Expected Result	Actual Result	Comments:
1	Run a frequency sweep from 14MHz-14.2Mhz with a step of 0.1MHz. This will be done to show the SWR at the 20m band. Adjust dipole length if needed to optimize SWR at 14.1MHz.	SWR<1.5	SWR=1.25	PASSED: This SWR at 14.1MHz shows that the design antenna is capable of receiving signal from the 20m band efficiently.. Now that this is confirmed, a sweep will be run across more frequencies to test the 10m, 30m, and 40m bands.
2	Run a frequency sweep from 5MHz-30MHz with a step of 1MHz. This will show the SWR and the 10m-40m bands.	SWR≤3 for 10m- 40m bands	SWR≤3 for 10m, 15m, 40m, bands	PASSED: From the frequency sweep, we can see that the antenna performed well and met the design target of a 3:1 SWR at the 10m, 15m, and 40m bands. Since we are designing a multiband antenna, it is difficult to receive the optimal signal at each amatuer band. The sweep confirmed that the antenna will receive clear signal at these amatuer bands.

Overall result = PASSED

Notes/Comments: The frequency sweep from 5Mhz-30Mhz showed 5 noticeable dips in SWR with the best SWR being at 14.1 MHz (20m band). The system also outputs very good matching at the 10m, 15m and 40m bands. Although every amatuer band cannot receive perfect signal, these 4 bands provide great functionality for an HF multiband antenna.

Approvals

The signatures of the people below indicate an understanding of the purpose and content of this document by those signing it. By signing this document, you indicate that you approve of the Project Plan.

Approver Name	Title	Signature	Date
Roberto Colon	Project Manager		11/30/2020
Joshua Ready	D2 Project Manager		12/01/2020
Karl Stephan	Faculty Sponsor		12/02/2020
Rich Compeau	Sponsor		12/02/2020
Mark Welker	Instructor		

Sections	Author	Word Count
1,2,2.1,5.1(1B)	Drew Schmidt	1024
3, 5.1(1A), 5.4(4B)	Jorge Blanco	925
4,5.2(2A),5.3(3C),5.3(3D)	Dennis Liao	1,863
2.2, 5, 5.2, 5.3, 5.4, Approvals	Roberto Colon	1,562

References

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US Bureau of Labor Statistics Latest Numbers

https://www.zillow.com/wimberley-tx/home-values/

-Vendor Sites Below for part cost research:

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1.02 Gannt Chart

Oct 21, 2020

Texas State University

Project manager	Roberto Colon
Project dates	Sep 13, 2020 - May 8, 2021
Completion	0%
Tasks	26
Resources	0

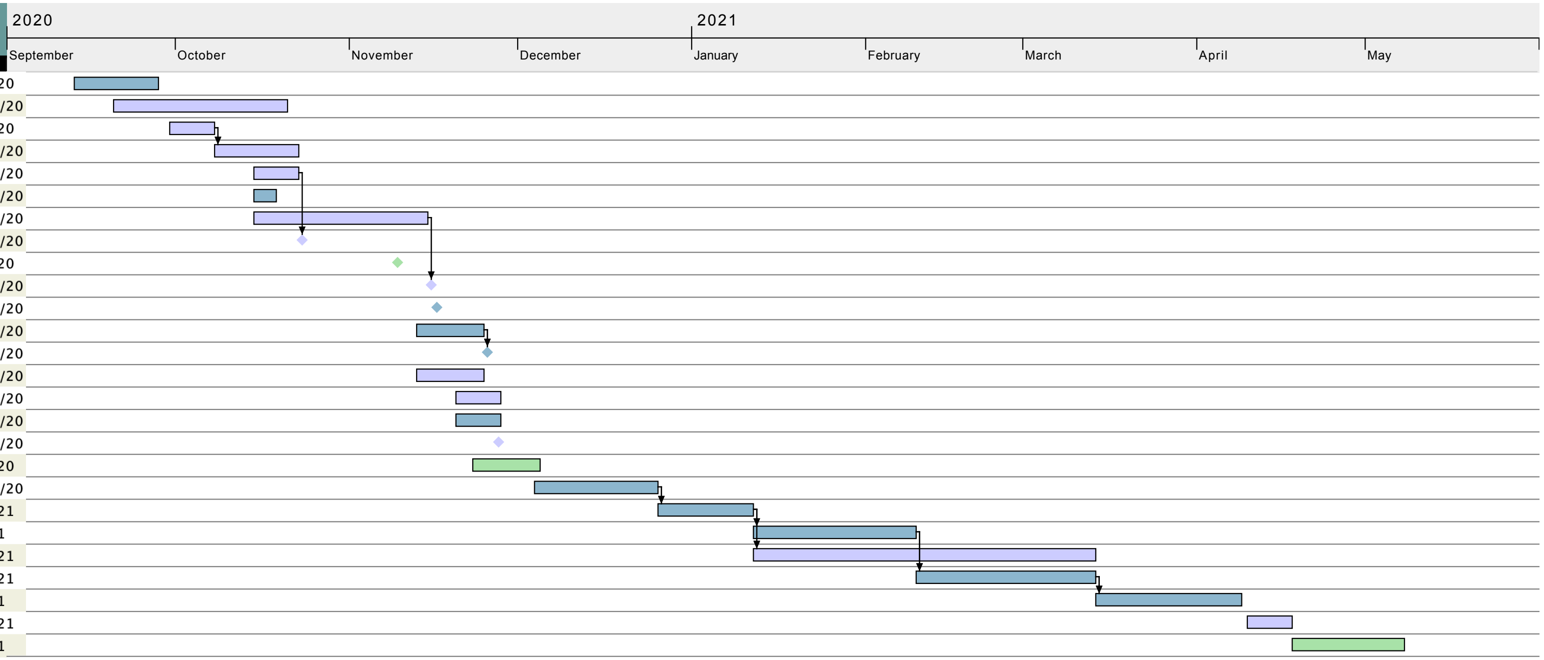
Blue Task: SDR subsystem task
Purple Task: 4NEC2 subsytem task
Green Task; SDR and 4NEC2 task

Tasks

Name	Begin date	End date
Setup SDR HF capability/Decide antenna configuration and setup	9/13/20	9/27/20
Code 4NEC2 subsytem	9/20/20	10/20/20
Run half-wave diple antenna simulation	9/30/20	10/7/20
Run simulations of complex antenna structures	10/8/20	10/22/20
Determine ladder line length in 4NEC2	10/15/20	10/22/20
Select antenna materials	10/15/20	10/18/20
Debug and test 4NEC2 code	10/15/20	11/14/20
Verify half-wave dipole 4NEC2 simulation	10/23/20	10/23/20
Initial Design Review	11/9/20	11/9/20
Correctly model a designed antenna in 4NEC2	11/15/20	11/15/20
VHF antenna setup	11/16/20	11/16/20
Install and test G5RV antenna	11/13/20	11/24/20
G5RV receives HD signals	11/25/20	11/25/20
Simulate and verify G5RV in 4NEC2	11/13/20	11/24/20
Make a 4NEC2 short video tutorial	11/20/20	11/27/20
Make video demo RTL-SDR receiving HF with a simple antenna	11/20/20	11/27/20
Design antenna efiienciency is imporved on 4NEC2	11/27/20	11/27/20
Preparation for Senior Design Day	11/23/20	12/4/20
Order and receive materials	12/4/20	12/25/20
Construct design antenna	12/26/20	1/11/21
Intial test of design antenna	1/12/21	2/9/21
Test and debug 4NEC2 code for final antenna design	1/12/21	3/13/21
Modify antenna design if necessary	2/10/21	3/13/21
Design and Construct final antenna	3/14/21	4/8/21
Verify final design antenna in 4NEC2	4/10/21	4/17/21
Final Reports and Presentation Preparation	4/18/21	5/7/21

Gantt Chart

Setup SDR HF capability/Decide ante...	9/13/20	9/27/20
Code 4NEC2 subsytem	9/20/20	10/20/20
Run half-wave diple antenna simulati...	9/30/20	10/7/20
Run simulations of complex antenna ...	10/8/20	10/22/20
Determine ladder line length in 4NEC2	10/15/20	10/22/20
Select antenna materials	10/15/20	10/18/20
Debug and test 4NEC2 code	10/15/20	11/14/20
Verify half-wave dipole 4NEC2 simul...	10/23/20	10/23/20
Initial Design Review	11/9/20	11/9/20
Correctly model a designed antenna ...	11/15/20	11/15/20
VHF antenna setup	11/16/20	11/16/20
Install and test G5RV antenna	11/13/20	11/24/20
G5RV receives HD signals	11/25/20	11/25/20
Simulate and verify G5RV in 4NEC2	11/13/20	11/24/20
Make a 4NEC2 short video tutorial	11/20/20	11/27/20
Make video demo RTL-SDR receiving...	11/20/20	11/27/20
Design antenna efiiencicy is impor...	11/27/20	11/27/20
Preparation for Senior Design Day	11/23/20	12/4/20
Order and receive materials	12/4/20	12/25/20
Construct design antenna	12/26/20	1/11/21
Intial test of design antenna	1/12/21	2/9/21
Test and debug 4NEC2 code for fina...	1/12/21	3/13/21
Modify antenna design if necessary	2/10/21	3/13/21
Design and Construct final antenna	3/14/21	4/8/21
Verify final design antenna in 4NEC2	4/10/21	4/17/21
Final Reports and Presentation Prepa...	4/18/21	5/7/21



Resources Chart

2020				2021				
September	October	November	December	January	February	March	April	May