Cellular Phone Transmission Detector and Display

ECE 445 Design Document

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1 Introduction

1.1 Objective

Radio astronomy and weather research often relies on the detection of weak signals that must be distinguished from surrounding radio-frequency (RF) background noise.[1] Though there are attempts to limit the bands used for such remote sensing research to those outside crowded domains, signals such as giant pulses from Crab-like pulsars and HI emissions from galaxies are found in bands dominated by communications and other interference.[2] In addition, the bands that can be used for observations are often limited by the attenuation effects of the Earth's atmosphere (allowing only frequency bands in the so-called radio window) and man-made radio frequency interference (RFI).[3] Internal RFI sources mainly include cellular devices and microwave ovens. The RF signal generated or received via active cellular transmission during a phone call, SMS sending/reception, and LTE connection completely overpowers the signals of interest received by the observatories. In fact, an equivalent cellular transmission originating from the Moon would still serve as disrupting interference inhibiting astronomical research on Earth.[4]

Our goal in this project is two-fold. First, it is to mitigate the internal RFI contributions of active cellular transmission through a detection-and-prevention plan of action. We will develop a cell phone transmission detector that would notify a user if there is significant power in a certain RF band of interest (corresponding to call, SMS, or data) nearby. This device will be developed such that it will be stationary and housed in a gate that every visitor to an RF observatory will walk through. The second goal of our project is to educate the public on RFI. We will do this by developing a visual display that describes the ambient RF signals detected in the room. This public outreach factor will portray to viewers the various RF frequency bands of interest and their corresponding signal strength in near-real-time.

1.2 Background

Cell phone transmissions are broken up into three distinct flavors: Code Division for Multiple Access (CDMA)[5,] Global System for Mobile Communications (GSM)[6,] and Long-Term Evolution (LTE)[7.] These different protocols span the implementations across various carriers for voice, SMS, and data transmission, and are all prevalent in today's world dominated by cell phones. Each also occupies a different space in the RF spectrum. The figures below illustrate proof of the existence of these signals. Additionally, different countries across the globe use different bands in the RF spectrum for CDMA, GSM, and LTE signals. In Puerto Rico, the Arecibo Observatory encounters this exact form of interference as a result of tourism to the site. In an effort to alleviate the problems caused by such interference, RFI mitigation techniques are being developed for the RF front-end, precorrelation, and postcorrelation (multiple points within the signal path).[2] However, these solutions are not enough to completely remove the noise from a nearby cell phone, nor are these techniques able to discern useful data from mere cell phone transmissions. Our detector will be self-contained, and each functional block of the detector system will be cheaper than currently available products.

1.3 High-Level Requirements

- The device must be able to detect two different frequency bands; the first band should center on CDMA, GSM, or LTE protocol bands of the United States, and the second band should center on a protocol band of typical cellular transmission in Puerto Rico.
- A display should show the relative strengths of the two active frequencies detected by the device.
- The device must notify the user or operator when a signal of a notable frequency is detected via a specific notification element (LED).

2 Design

The high-level design of this device is composed of four main modules: a power supply module, a receiving module, a detection and notification module, and a display generation module. The two receiving modules and two power detection and notification modules serve to distinguish between two different frequency bands of interest. The power supply will provide necessary power, at various voltages, to our entire system. The receiving modules receive a signal from an antenna, and consists of a bandpass filter, an amplifier, and a half-wave rectifier. The antenna should provide a usable signal in the presence of active RF transmission at a distance of up to 1 meter. The detection module will determine if a non-trivial amount of power is present in relevant frequency bands and notify the device's user accordingly via an LED. Lastly, the display module, using a Raspberry Pi and installed Python, will provide a real-time visual representation of present RF signals.

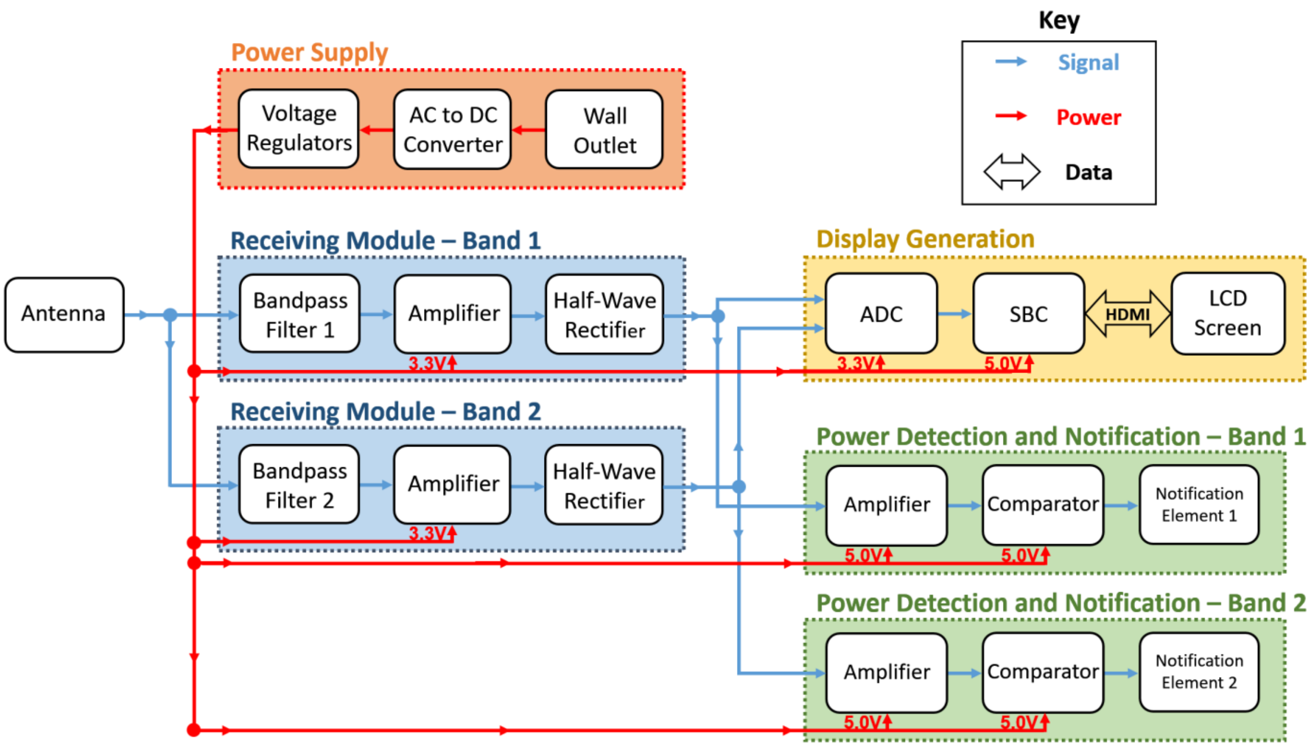

Figure 1: *Device Block Diagram*

2.1 Power Supply Module

2.1.1 Wall Outlet

A standard wall outlet will provide power to our entire device. It should provide consistent power at its advertised voltage and frequency. Additionally, wall outlet converters can be added to the device as necessary to adapt to country-specific regulations.

Requirements	Verification
1. Wall outlet must provide power to +/-5% of U.S. standard for wall outlets (120V at 60Hz with a total load less than 3A)	a. Use a properly-configured and correctly-calibrated multimeter to probe wall outlet for correct voltage and frequency

2.1.2 AC-DC Converter

All of the ICs used in the other three modules require DC supply voltages. A purchased power converter, the Wonderoto W-T5000, will be used to take wall input and output a constant 12V DC – high enough to only fixed voltage regulators to step it down for the remainder of our circuit's components.

Requirements	Verification
1. Converter must provide 12V DC to +3V, -1V under a total load less than 3A	a. Plug AC-DC converter into a wall outlet b. Use a multimeter and breadboard with resistor network to ensure constant 12V DC output under ~3A load

2.1.3 Voltage Regulators

Voltage regulators will be used to accurately power each component in the device. They take in input from the AC-DC Converter and output supply power to various ICs in the schematic. We will be using the typical TI voltage regulators - the LM1117. This helps protect our circuit as well as the users of the device. We need two of these regulators; one for each of our desired DC voltages, 5V, and 3.3V.

Requirements	Verification
1. Provide each regulator's desired voltage: a. 5V +/- .5V under 2A load b. 3.3V +/- .2V under 200mA load	a. Connect the AC-DC converter to the wall outlet b. Connect voltage regulators to AC-DC converter c. Use DMM with a resistor network to ensure proper, stable voltage regulation under desired loads

2.2 Receiving Module

Bench tests were performed to determine the frequency bands relevant for detection of US active cellular transmission. The results of these tests are shown below. When making a call, there is a clear spike in power at 836MHz, with a relatively short bandwidth of less than 1.5MHz. The design of this project includes the detection of two frequency bands of interest, one representing the below transmission (which, in the lab, has been measured as low as ~710MHz) and another representing transmission in a frequency range seen in cellular communications in Puerto Rico, centered on 1.7GHz.[8]

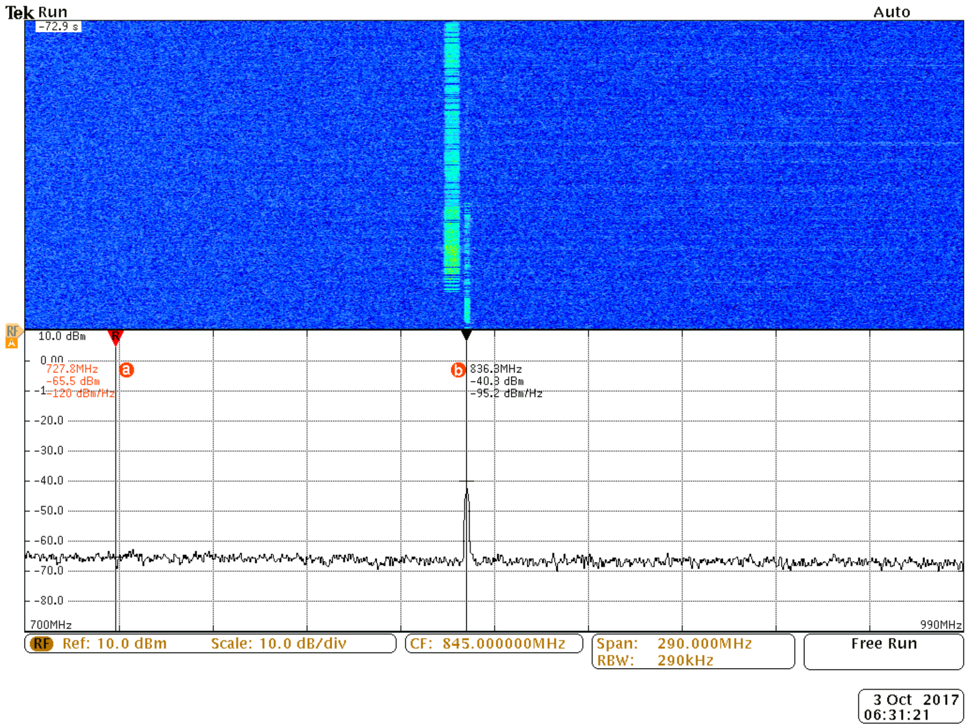

Figure 2a: Presence of AT&T cellular signal peak (~836MHz center) in local frequency spectrum

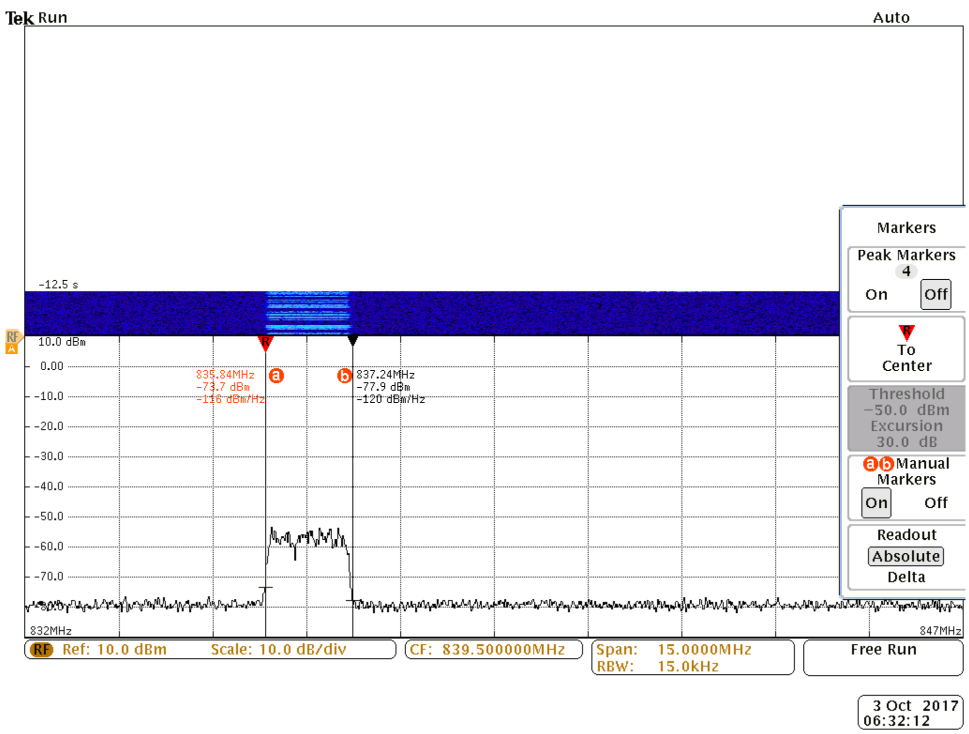

Figure 2b: Bandwidth of cellular signal (~1.5MHz shown in Figure 1a

2.2.1 Antenna

The device will receive RF signals via an external, wideband (698MHz – 2.69GHz) antenna – the W5084K from Pulse Electronics via Mouser. The antenna's band of reception is sufficient for our needs – other antennas either don't cover both of our bands of interest, or they do not reach low enough frequencies (many go as low as ~715 MHz, but our signals measured can reach ~710 MHz). We require the antenna to be capable of receiving a useful signal at a distance of up to 1 meter. "Useful" for our device can be considered a signal that is strong enough to ensure proper function of subsequent components/modules.

Requirements	Verification
1. Antenna must be matched at 50Ω +/- 10% in the frequency bands of interest (650-900MHz and 1500-1900MHz)	a. Test antenna match to antenna with a network analyzer to ensure matching within 10% in our desired band
2. Provides a received signal strength of at least –40dBm +/- 3dBm (depending on direction) at a distance of 1 meter	a. Measure power received at filter using lab equipment (oscilloscope, DMM) and ensure ~-40dBm reception

2.2.2 Bandpass Filters

The bandpass filters, designed with resistors, inductors, and capacitors, will attenuate unwanted frequency bands above and below our two bands of interest. They directly take input from the antenna and feed into the RF amplifiers. The filters are required in order to remove nearby frequencies on either side of our bands of interest (namely, for the low BPF for example, FM radio broadcasts below the band and WiFi/Bluetooth above the band).

The two center frequencies for the two filters, respectively, are 720MHz and 1.7GHz. Details for choosing these center frequencies, bands, and the corresponding BPF parameters can be found in the *Tolerance Analysis – Lower Bandpass Filter* and *Upper Bandpass Filter Design* sections.

Requirements	Verification
1. Lower frequency BPF must observe at least 3dB fall from 720MHz center frequency to cutoffs of 250MHz (to eliminate FM radio) and 1.5GHz (to eliminate Bluetooth/Wifi). Upper frequency BPF must observe at least a 0.5dB fall from 1.7GHz center frequency to lower cutoff of 700MHz (lower band) and at least a .3dB fall from 1.7GHz to upper cutoff of 2.5GHz.	a. Generate a 1V 250MHz signal via signal generator (generate 700MHz signal if testing Upper band BPF) b. Feed the signal as input into the BPF and output result to an oscilloscope c. Make sure amplitude of output signal corresponds to accompanying dB drop-off specified d. Repeat for 1.5GHz (elimination of upper band) (or repeat for 2.5GHz if testing Upper band BPF) e. Repeat for Upper frequency band

2.2.3 RF Amplifier

In order to ensure proper function of the remainder of our circuit, the signal strength after the bandpass filter must be amplified. An RF amplifier, SBA5089Z, will be used. It will (with its ~20dB gain) boost the bandpass filter's output signal to something discernible by our detector circuit and detection/display modules post-rectification.

Requirements	Verification
1. Amplifier must provide +20dB +/- 3dB gain with an input power between -30dBm and -50dBm in each of the frequency bands of interest (centers of 720MHz and 1.7GHz).	a. Generate a 720MHz, -30dBm signal using a signal generator (1.7GHz for upper band) b. Feed the signal into the amplifier c. Measure output voltage across load resistor with oscilloscope and make sure the voltage range of the output is within the range specified d. Repeat across the specified power and frequency range

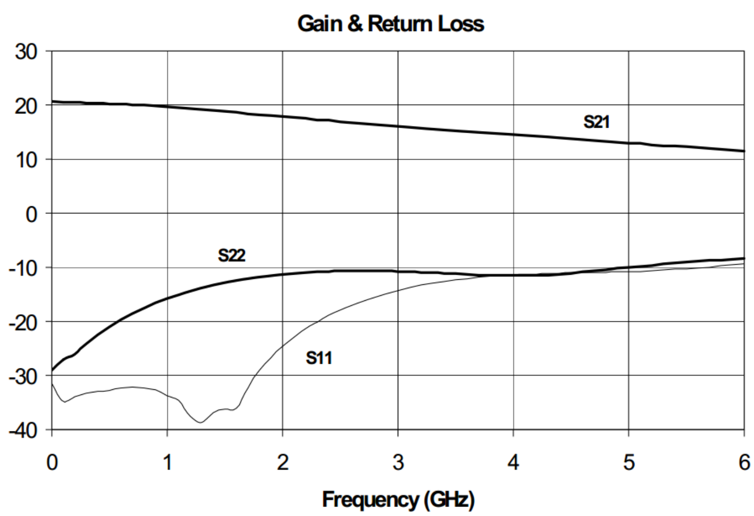

Figure 3: S parameters for amplifier SBA5089Z

The device provides high forward voltage gain. The above figure indicates that we have a gain of ~20dB at the first frequency band centered at 720 MHz (again, details regarding the selection of a 720MHz center are described in the *Tolerance Analysis* section), and a gain of ~18dB at the second frequency band centered at 1.7GHz.

2.2.4 Half-wave Rectifier

The subsequent elements in our circuit use DC voltages. Thus, we use a half-wave rectifier, formed with a Schottky diode BAT54 and a capacitor, to transform the incoming AC signal into a usable DC signal. This DC output voltage will then feed into the display module's analog-digital converter so that it can read the voltage input. The DC voltage will additionally feed into the detector circuit for determining whether the band in question is polluted with RFI.

Requirements	Verification
1. Ripple voltage must fall within 5% of the peak voltage	a. Generate a 800MHz 3V peak sinusoid using a signal generator b. Feed the signal into the rectifier

	c. Measure output voltage across load resistor with oscilloscope and make sure the voltage range of the rectified signal is no more than 5% of the original peak voltage d. Repeat with various amplitudes of same frequency and verify the 5% condition

2.3 Power Detection and Notification Module

2.3.1 DC Amplifier

The DC amplifier, in the form of a low power dual CMOS operational amplifier LMC6022IM, will serve to amplify the low power signal as necessary to be properly compared to a reference voltage of 3.3V in the next block. The current design biases the dual amplifier to gains of 1 and is only acting as a buffer; however, once tests are performed, the biasing might be altered to increase or decrease this gain accordingly so that the signal may be compared with the reference voltage.

Requirements	Verification
1. Match input voltage (gain=1) with less than 1.5% error with a supply voltage of 5V	a. Create closed circuit on breadboard with the following specifications: V+=5V (DC power supply), large signal gain = 1 with biasing resistors (R_g=1K, R_f=0), V_{IN}=3.3V (DC power supply), V_{OUT} connected to multimeter b. Ensure that V_{OUT}=3.3V +/- 50mV (1.5% tolerance) c. Conduct test for both comparators in IC

2.3.2 Comparator

The comparator, a quad differential comparator LM339, will be used for the actual thresholding logic for determining if there's an unexpected spike in the aforementioned frequency ranges. The amplified signal will be compared to a reference voltage of 3.3V.

Requirements	Verification
2. Switch from low to high with less than +50mV overdrive voltage in under 100ms	d. Create closed circuit on breadboard with the following specifications: V_{CC}=5V, V_{ref}=3.3V, V_{OUT} connected to oscilloscope, V_{IN+} connected to DC Power Supply and oscilloscope e. Sweep V_{IN+} from 0V to 5V and record two curves (V_{IN+} and V_{OUT}) from oscilloscope f. Ensure that low to high switching occurs with V_{IN+}-V_{ref}<50mV in under 100ms
3. Switch from high to low with V_{ref}-V_{IN+} less than 50mV in under 100ms	a. Create closed circuit on breadboard with the following specifications: V_{CC}=5V,

	V_{ref}=3V, V_{OUT} connected to oscilloscope, V_{IN+} connected to DC Power Supply and oscilloscope b. Sweep V_{IN+} from 5V to 0V and record two curves (V_{IN+} and V_{OUT}) from oscilloscope c. Ensure that high to low switching occurs with V_{IN}+>V_{ref}-50mV in under 100ms

2.3.3 LED

This will be our notification element. If significant RFI is detected in the specified bands then this element will indicate it, with either a high or a low.

Requirements	Verification
1. Verify operation at 2V forward bias with 20mA forward current	a. Connect to closed circuit on breadboard, with DC Power Supply supplying 2V and 20mA b. Verify clear visibility of LED c. Supply 0V forward bias (connect both nodes to GND) and verify LED off

2.4 Display Generation Module

2.4.1 Single-Board Computer (SBC)

The SBC (a Raspberry Pi 3 Model B) will serve to take in the output from the half-wave rectifier and manipulate it to a usable input for the LCD screen. This will involve installing Python onto the SBC and using a pre-written plotting library to plot data in near-real-time.

Requirements	Verification
1. No wireless transmission from Raspberry Pi 3 should be detected	a. Turn on Raspberry Pi b. Place antenna on input channel of spectrum analyzer and set view to 1GHz ~ 4GHz c. Place Raspberry Pi near antenna and check for any spikes in spectrum plot d. Especially keep and take note of BT ranges (2.402GHz ~ 2.480GHz) and WiFi ranges (2.400GHz ~ 2.4835GHz)

2. Must read voltage fed to GPIO to a precision of 5% (within 0-3.3V)	a. Using a DC Power supply, sweep voltage from 0 to 3.3V b. Measure values for the sweep and make sure the recorded value lies within 5% of the supply voltage input

2.4.2 LCD Screen

This screen will allow easy visualization of our detector circuit – it will display a real-time graph depicting the relative strength of signals within our band of interest.

Requirements	Verification
1. Can take HDMI input	a. Verify HDMI input is functioning by projecting laptop screen onto LCD screen via HDMI cable

2.5 Schematics

2.5.1 Power Supply Schematic

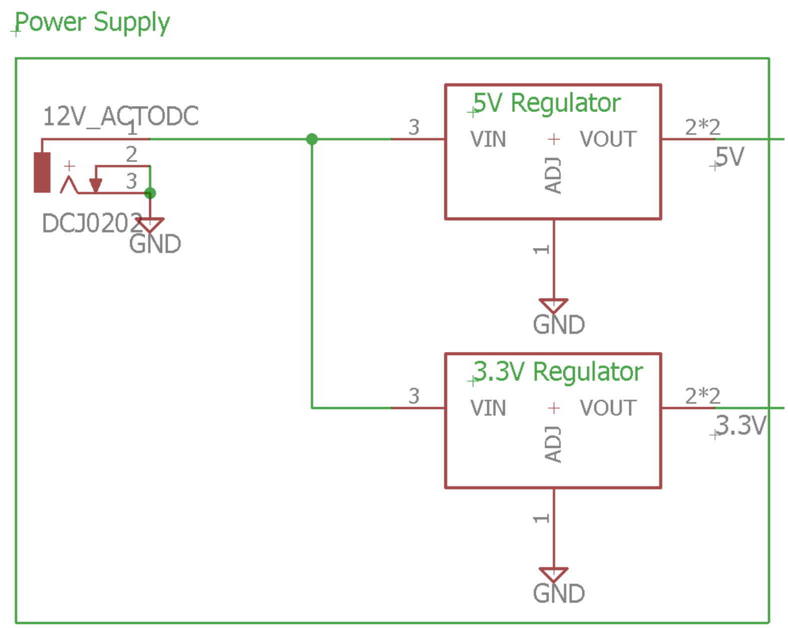

Figure 3a: Power Supply module schematic

2.5.2 Receiving Module Schematic

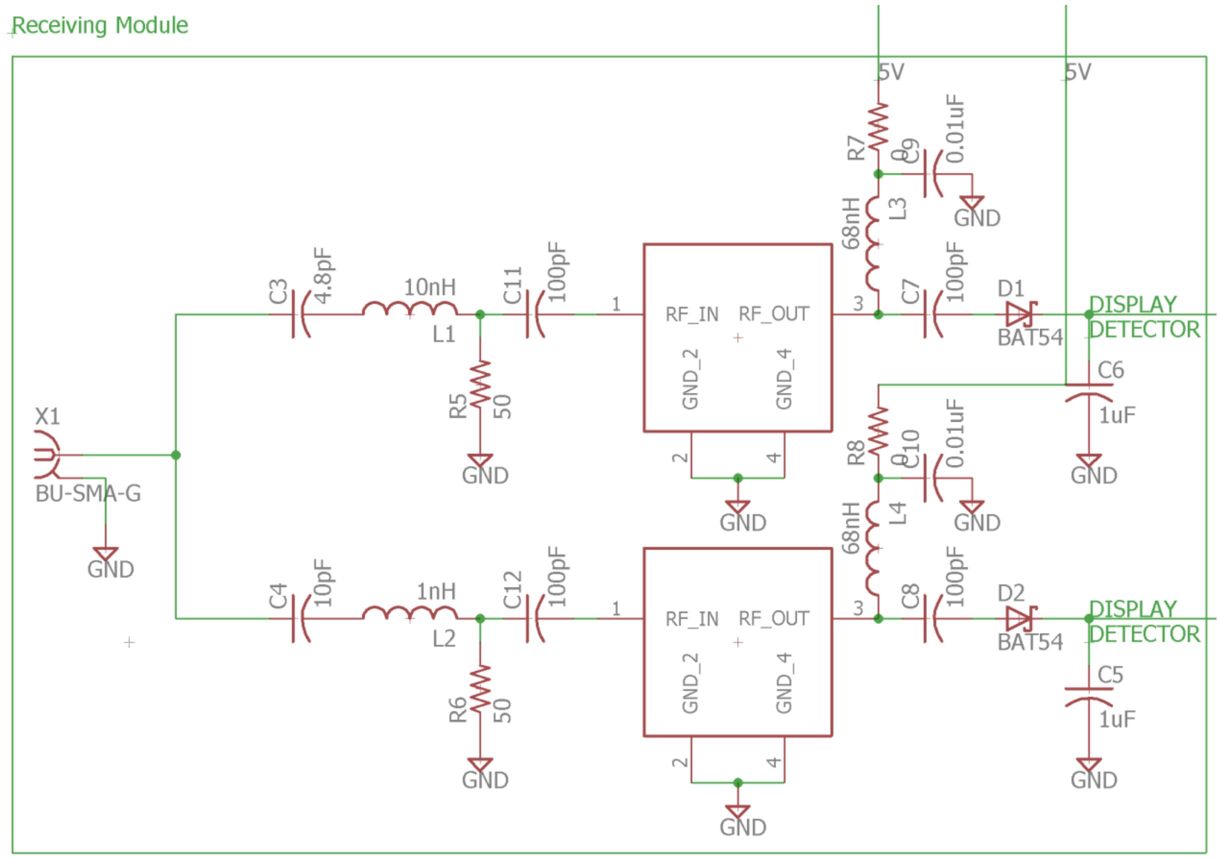

Figure 3b: Receiving module schematic

2.5.3 Power Detection and Notification Module Schematic

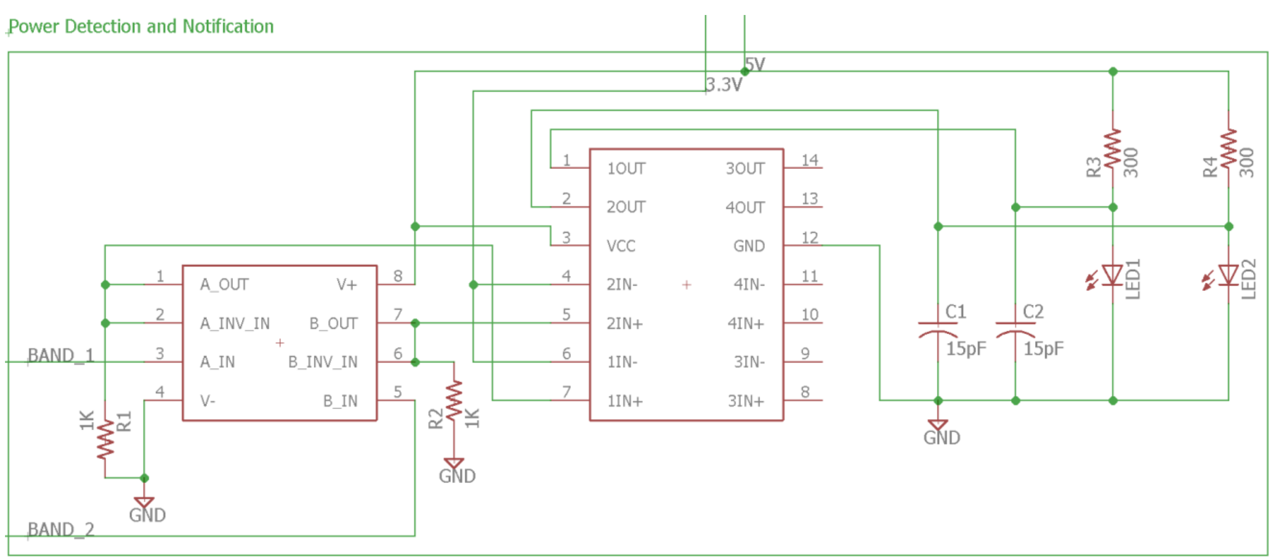

Figure 3c: Power Detection and Notification module schematic

2.5.4 Display Generation Module Schematic

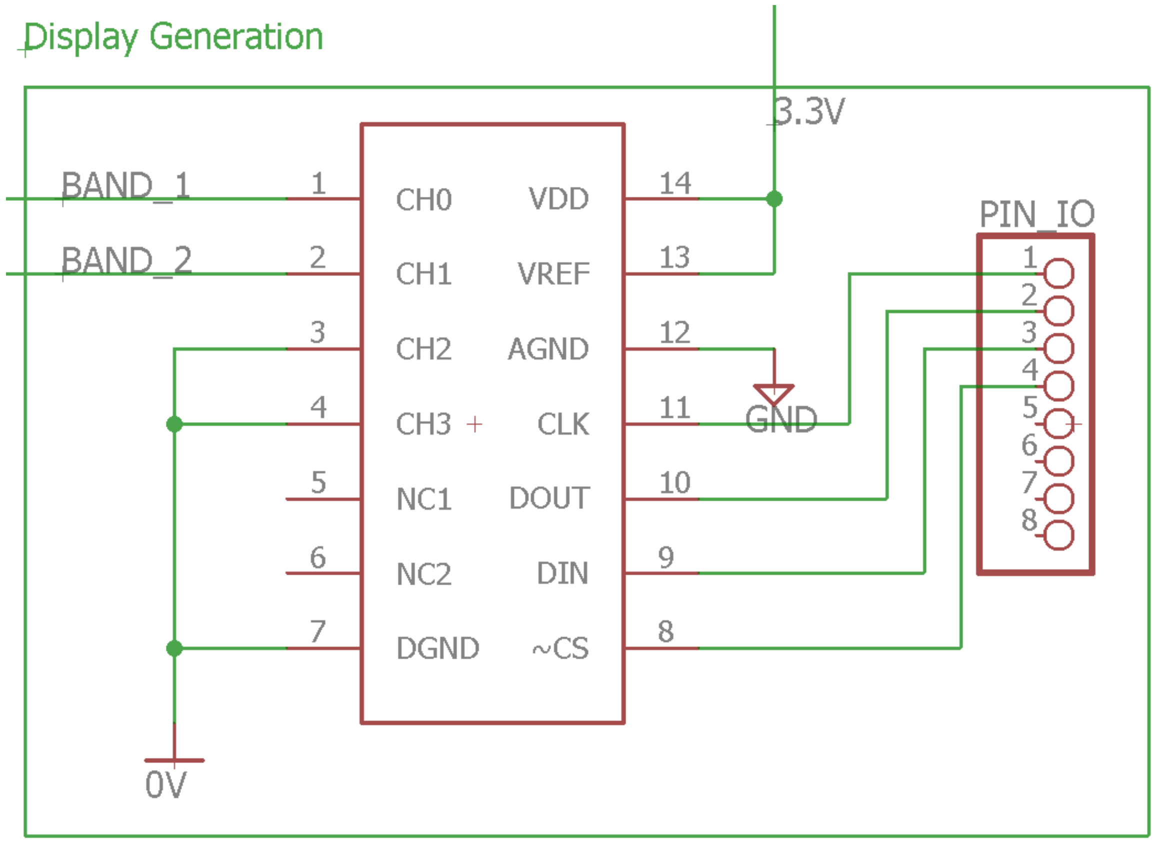

Figure 3d: Display Generation module schematic

2.6 PCB Design

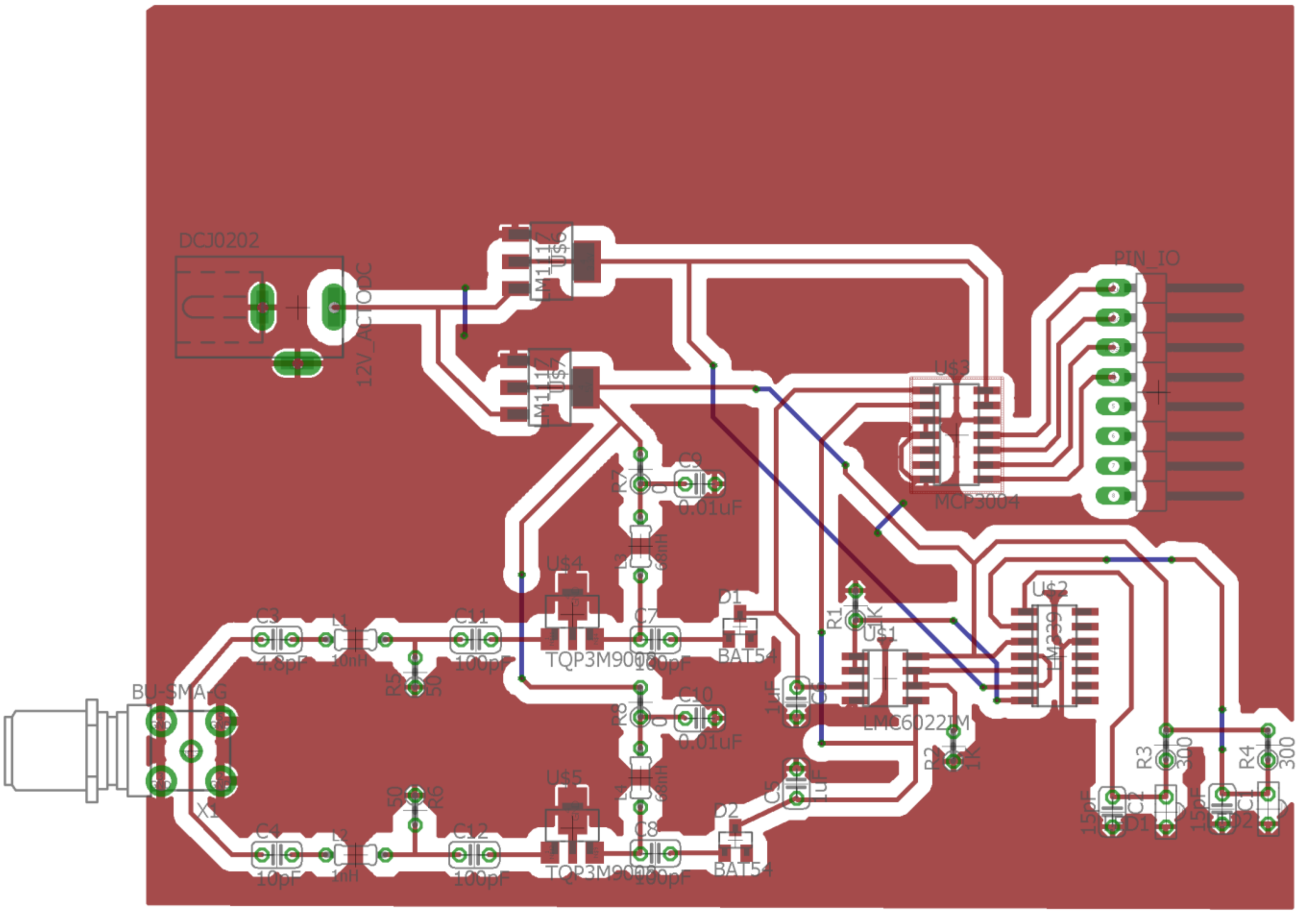

Figure 4: PCB design

2.7 Tolerance Analysis – Lower Bandpass Filter

It has been determined that the low-frequency bandpass filter is a critical component on which the success of this project is dependent. We focus on this band for tolerance analysis because it is the BPF that isolates a frequency range easily tested with real cell phones (US transmission frequencies). This BPF must properly attenuate high frequency signals while passing the lower frequency signals associated with our personal phones.

Bench test experiments, as mentioned above, indicated spikes in power associated with frequencies centered on 836MHz. Additional tests not explicitly shown described frequencies detected at ~715MHz. We therefore arrived at our aforementioned lower band of interest: 650MHz to 900MHz. Since BPF frequency responses are typically elongated on the right, higher frequency side, we center the lower BPF at 720MHz to detect all frequencies in this band with minimal attenuation. Additionally, this makes the calculations solve to capacitor and inductor values that are close to values we can easily find (close to a value with only a tenths place digit).

In order to design the bandpass filter needed to extract this band of interest, we must compute the proper capacitor and inductor values to use (assuming we use a 50Ω resistor as a load). We settled on the use of a series RLC bandpass filter in order to achieve a tolerable selectivity between frequency bands (650MHz-900MHz). The following formula and calculations led us to our corresponding values of C and L.

$$f_c = \frac{1}{2\pi\sqrt{LC}} \Rightarrow LC = \left(\frac{1}{2\pi f_c}\right)^2$$

$$\xrightarrow{f_c = 720\,MHz} C = 4.8pF, L = 10nH$$

Equation 1: Lower band bandpass filter L, C calculation

Building the circuit and simulating the results using Keysight ADS gives a better idea of how our design will perform:

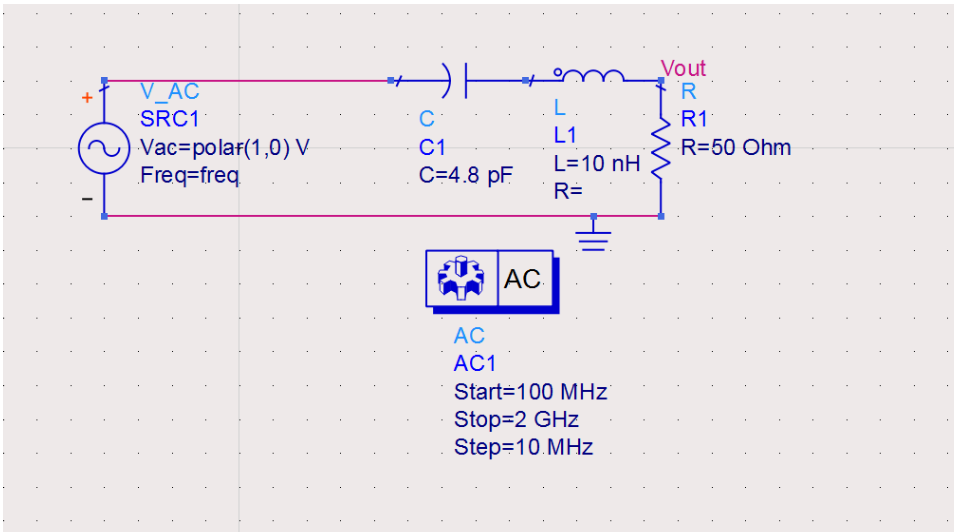

Figure 5a: Lower band bandpass filter schematic with ideal component values

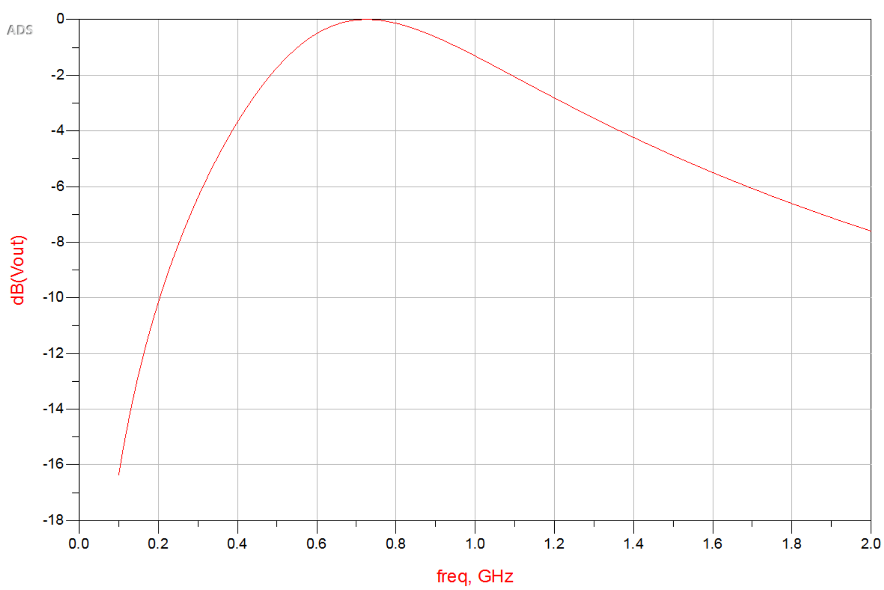

Figure 5b: Lower band bandpass filter simulation with ideal component values – the -3dB frequencies are 430MHz and 1.22GHz

These calculations are done with the nominal, ideal values of the capacitor and inductor. However, we must investigate what happens if the tolerance of our components comes into play. The 4.8pF capacitor used will have approximately a 0.5pF tolerance, and the 10nH inductor will approximately have a 5% tolerance, or 0.5nH tolerance. We first see what happens when we use the higher bounds of the tolerance (5.3pF capacitor and 10.5nH inductor).

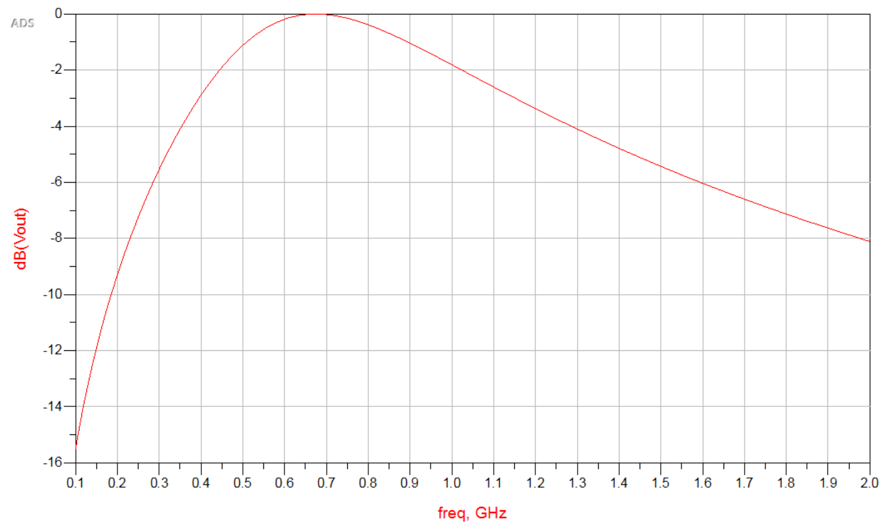

Figure 5c: Lower band bandpass filter simulation with highest component values – the -3dB frequencies are 395MHz and 1.16GHz

As shown in our simulation, our bandpass filter's center frequency shifted approximately 35MHz to the left. However, the –3dB frequencies on either side of the filter's center are well within our bounds discussed in our design requirements (250MHz and 1.5GHz). This filter will easily attenuate FM radio broadcasts and WiFi/Bluetooth signals in the higher bound case.

We then shift our simulation to account for the lower bound tolerance case. In this simulation, we subtract from each of the ideal values (4.3pF capacitor and 9.5nH inductor). The lower bound simulation is shown below.

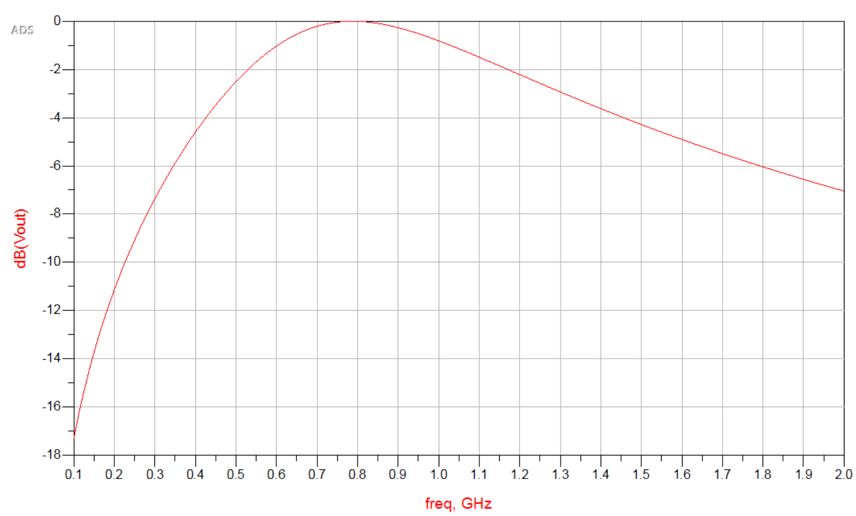

Figure 5d: Lower band bandpass filter simulation with lowest component values – the -3dB frequencies are 470MHz and 1.31GHz

Again, our filter's center frequency has shifted. We see, once again, that this filter is also easily attenuating signals at or below 250MHz as well as signals at or above 1.5GHz. Our filter is able to withstand a shift in its realized component values within advertised tolerances, whether the components are shading high or low.

2.8 Supplementary Calculations and Figures

2.8.1 Upper Bandpass Filter Design

Please refer to *Tolerance Analysis – Lower Bandpass Filter* for details on the calculations associated with the lower bandpass filter.

As our device is focused on detecting active cellular transmission in observatories such as the Arecibo Observatory, Puerto Rico, we specify parameters for the higher-frequency BPF according to those cell phone frequency bands in those regions. The UMTS B4 band is centered at 1700MHz (1.7GHz) and incorporates call/SMS as well as LTE use.[8] For this particular BPF design, we are not concerned with filtering out WiFi frequencies (~2.4GHz) because those signals do not exist by default in the Arecibo Observatory. This, of course, makes it a significantly less critical component of our project; this is advantageous due to the considerable difficulty of building a sharp bandpass filter at high frequencies with discrete components. The same formula and calculation method bring us to our high-BPF values of C and L.

$$f_c = \frac{1}{2\pi\sqrt{LC}} \Rightarrow LC = \left(\frac{1}{2\pi f_c}\right)^2$$
$$\xrightarrow{f_c = 1700\,MHz} C = 8.8\,pF,\, L = 1\,nH$$

Equation 2: Upper band bandpass filter L, C calculation

It should be noted that exact calculations with L=1nH yield C=8.8pF, as seen above, but we approximate this as C=10pF due to the more easily obtained 10pF capacitor. This approximation does not affect the BPF frequency response considerably. We conduct all simulations with the 10pF approximation.

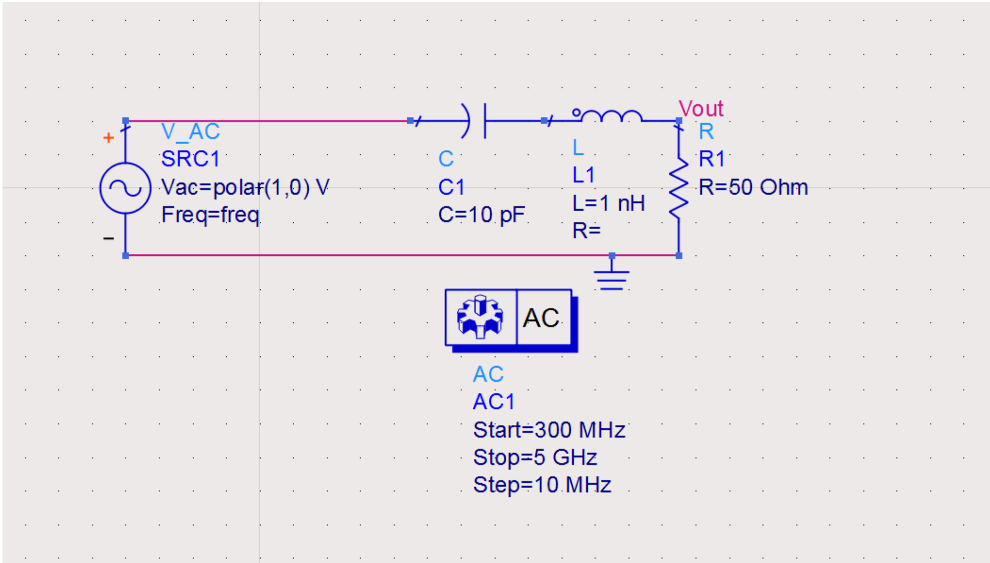

Figure 6a: Upper band bandpass filter schematic

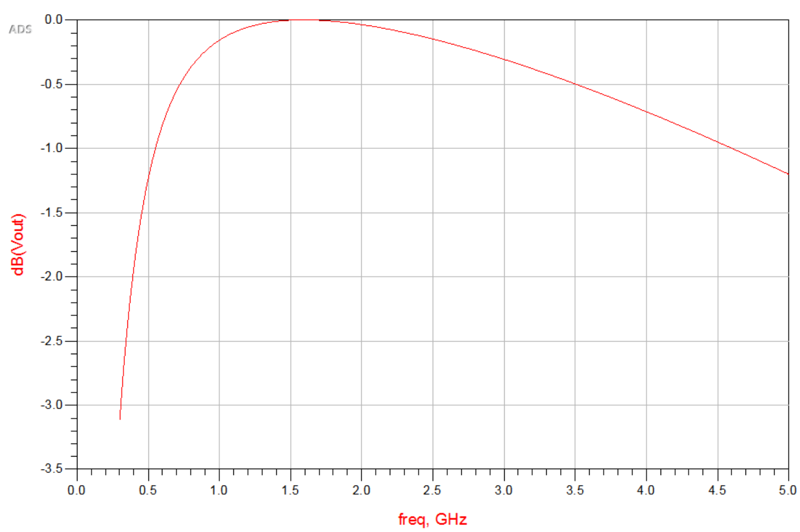

Figure 6b: Upper band bandpass filter L, C calculation

2.8.2 RF Signal Strength

To get an idea of what our sample signal will look like, we carried out experiments in the senior design laboratory at the RF benches, testing the sensitivity of the antenna to cellphone RFI. We can then plot the signal strength of our cellphones as a function of distance from our antenna from these measurements.

$$dBm_1 = dBm_0 - 10.0\gamma \log_{10}\left(\frac{r_1}{r_0}\right)$$

Equation 3: Signal strength as related to distance from source

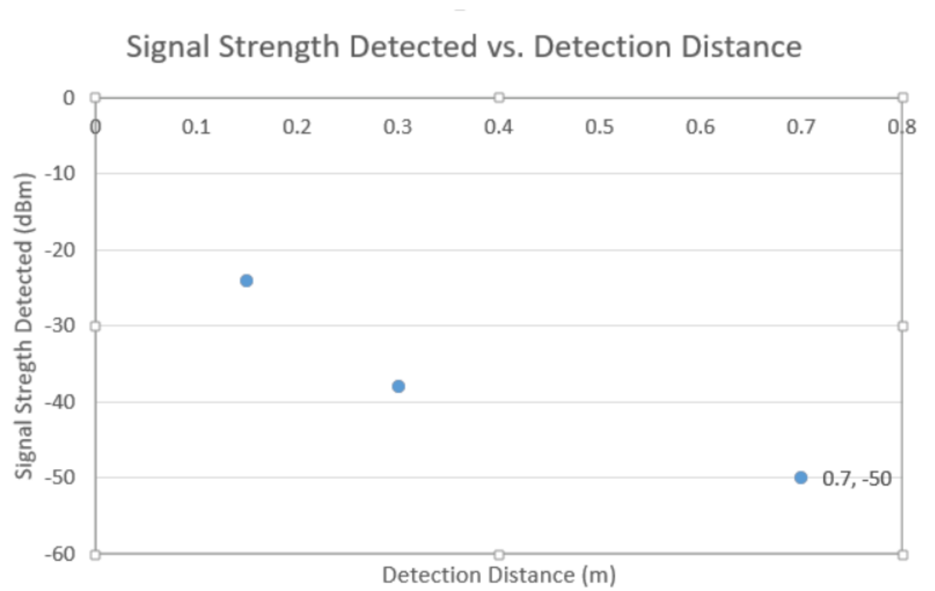

Figure 7: Ideal Signal Strength vs. Distance relationship (blue points are measured signals). The relationship is roughly 1/r.

The above observation is not portrayed with a screenshot in this report. We use this observation anyway, however, to resemble the best-case scenario in terms of power detected.

2.8.3 Transmission Line Implications

RF signals of interest are around 650-900MHz and 1500-1900MHz. Overestimating this as ~2GHz, we calculate the wavelength as 0.15 m. Using a transmission line is recommended when the wire length is longer than 1/10th of the wavelength. Therefore, we can avoid using a transmission line if the wire length is less than 0.015 m, or 1.5 cm. This, at a PCB level, can be implemented with proper caution and attention to detail.

3 Production Costs and Progress Schedule

3.1 Production Costs

3.1.1 Labor Cost

A typical ECE Illinois graduate can earn around $40 an hour in the industry, so we assume that each of our three team members' time is valued at $40 an hour. We estimate that a working prototype can be completely finished within the 16 weeks of the course. We also assume that each of us spends a consistent 15 hours a week working. This leads us to a final labor cost calculated by:

$$3[people] \times \frac{15[hrs]}{[week]} \times 16[weeks] \frac{40[\$]}{[hr]} \times 2.5 = \$72,000$$

Equation 4: Cost calculation for 3 team members' labor

3.1.2 Parts Cost

Table 1: Component manufacturing and pricing information

Part Description	Manufacturer	Part Number	Quantity	Cost (Individual)	Cost (High Volume)
Wideband Antenna	Pulse Electronics	W5084K	1	$16.84	$10.18
LCD Screen	Waveshare	5inch HDMI LCD (B)	1	$45.99	$35.99
Raspberry Pi (with OS SD card)	Raspberry Pi	Pi 3 Model B	1	$49.99	$48.49
AC-DC Converter	Wonderoto	B01IR2Y91S	1	$15.99	$15.99
Assorted ICs, resistors, capacitors, inductors, diodes, LEDs	Various	Various	N/A	$20.00	$5.00
TOTAL				**$148.81**	**$115.65**

3.1.3 Total Cost

As seen from our calculations, the initial cost of producing our first prototype and working device is our labor cost plus our individual parts cost: $148.81 + $72,000 = $72,148.81. From there, disregarding maintenance and assembly, we could produce additional units at $115.65 per device.

3.2 Progress Schedule

Table 2: Progress schedule split by team member

Week	Shawn	Anish	AJ
9/11	Investigate methods to display data on screen	Investigate RFI concerns at observatories and the frequency bands of concern	Begin initial design of version 1 of RF front end design
9/18	Propose final display method	Investigate common methods of detecting cellular-frequency RF	Finalize front end RF block design v1; begin version 1 power block design
9/25	Investigate SBCs available for use	Select viable frequency bands for design	Begin RF front end block design and component selection version 2; finalize v1 power block design; begin version 1 BPF design
10/2	Finalize choice for SBC and LCD	Finalize design of RF detector circuit module, using two parallel branches of amplifiers and comparators	Finalize RF front end component selection and design v2; finalize BPF v1 design
10/9	Place order for Raspberry Pi and necessary peripherals (wall adapter, SD Card, cables, LCD screen)	Place orders for RF-domain amplifiers as well as RF power detectors to use as benchmarks for performance if necessary	Place orders for necessary parts; begin antenna and BPF function testing
10/16	Configure Raspberry Pi settings and install necessary packages for development	Work with AJ to begin prototyping and modularly testing of RF front end, including certain parts that I am more familiar with (RF amplifier)	Begin prototype assembly of RF front end (antenna, BPF, RF amplifier, rectifier) and power block; begin modular functional block testing of RF front end and power supply

10/23	Setup the SPI interface for the Raspberry Pi and configure the LCD screen	Begin tweaking DC amplifier biasing in power detection and notification module according to input power received from receiving module	Planned bugfixes and tweaking of circuit parameters based on previous test
10/30	Test arbitrary input voltage signals (0-3.3V) as input to ADC and verify Raspberry Pi reads SPI data correctly	Complete final biasing requirements and design for power detection and notification	Complete antenna->BPF integration
11/6	Pipe SPI data stream into plot for display	Work with AJ to interface the receiving module with power detection and notification module	Complete power supply module integration
11/13	Solder pinout header and ADC chip onto PCB	Begin documentation early; work with AJ to interface different modules properly	Complete RF front end integration; begin final modular tests and debugging
11/20	Thanksgiving Break	Thanksgiving Break	Thanksgiving Break
11/27	Verify and integrate PCB design for ADC to pinout header to offboard Raspberry Pi	Finalize interfaces between modules and work with Shawn to adjust output from receiving module for input into ADC	Mock demo; finalize assembly of RF front end and power supply; final testing and bugfixes
12/4	Prepare final presentation and paper	Prepare final presentation and report	Begin preparing lab notebook, presentation, and paper for final submission
12/11	Present project and finalize final paper	Present project and finalize report	Finalize lab notebook submission, final presentation, and final paper

4 Safety and Ethics

There are a couple things we need to keep in mind when designing this project, the most important of which lies in the power supply side. We will be powering various elements of our circuit with a wall outlet, thus we need to take extra caution when converting the 120V AC wall outlet to 12V DC with our AC-DC converter so that we avoid possible electric shock and other forms of bodily harm in accordance with Section 1 in the IEEE Code of Ethics.[9]

One of the main issues we must keep in mind is that we must abide by FCC regulations. This will most likely not be an issue if we are only receiving RF signals, however we must still take precaution to not arbitrarily transmit waves. This could result in problems such as jamming signals, which is not only illegal, but would defeat the purpose of the detecting RFI in the first place.

A key ethical point we deal with stems from the nature of this project, namely that we are "to improve the understanding of technology; its appropriate application, and potential consequences;" (IEEE Code of Ethics #5).[9] One of the goals of this project is to visually educate the visitors of the Arecibo Observatory about the effects of RFI, which affects the measurements carried out by researchers.

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