ECE 445
Fall 2017

RFI Detector
Project Proposal

September 21, 2017

Team 13: Jamie Brunskill
Tyler Shaw
Kyle Stevens

TA: Zipeng Wang

1 Introduction

1.1 Objective

Radio frequency interference from cell phones affects measurements taken at the Aricebo Observatory in Puerto Rico. The observatory asks visitors to turn phones off or place them in airplane mode, but they do not always obey. Our goal is to create a device that will be able to detect the presence of RF signals given off by cell phones. The frequencies of interest will be the cellular bands used in Puerto Rico. The device will then display using LEDs what it detects: either green for No Transmission Present or red for Cellular Transmission Present. This will allow the employees at Arecibo to manually check groups of visitors to ensure that the guests comply with their cell phone policies.

1.2 Background

The radio observatory in Arecibo, Puerto Rico uses antennas to measure radio frequency energy in order to gather scientific insight into space and the upper atmosphere. This research can be impacted by outside interference from external sources, one example being cellular phones. Phones typically transmit signals between 0 dBm and 30 dBm [1], which is enough power to signficantly impact data collection. Many visitors of the observatory who carry cell phones are unknowingly transmitters of unwanted RF signals that can affect the measurements taken by the equipment on-site. Cell phones, when activated, frequently send these signals out unless they are turned off or the phone is placed in airplane mode. Even when asked, some people do not understand the harm they can do with their cellular devices and choose to not follow instructions.

1.3 High Level Requirements

1. Device must be able to properly sense an RF signal with transmit power above -15 dBm for frequencies 704-849 MHz and 1710-1915 MHz.

2. Device correctly detects presence of these interfering signals from up to 1 meter away and displays the results of the detection.

3. The device should be hand-held for use by on-site personnel.

2 Design

Figure 1 shows the block diagram for the design of the RFI detector. The RF unit consists of two distinct receive paths, each with a unique bandpass filter that will pass the two frequency bands of interest. RF detectors will be used to measure the power, and the outputs from these will be measured with an ADC. This data will be processed by the microcontroller and the user will be alerted to the presence of interference should it exist. The system will be powered with alkaline batteries.

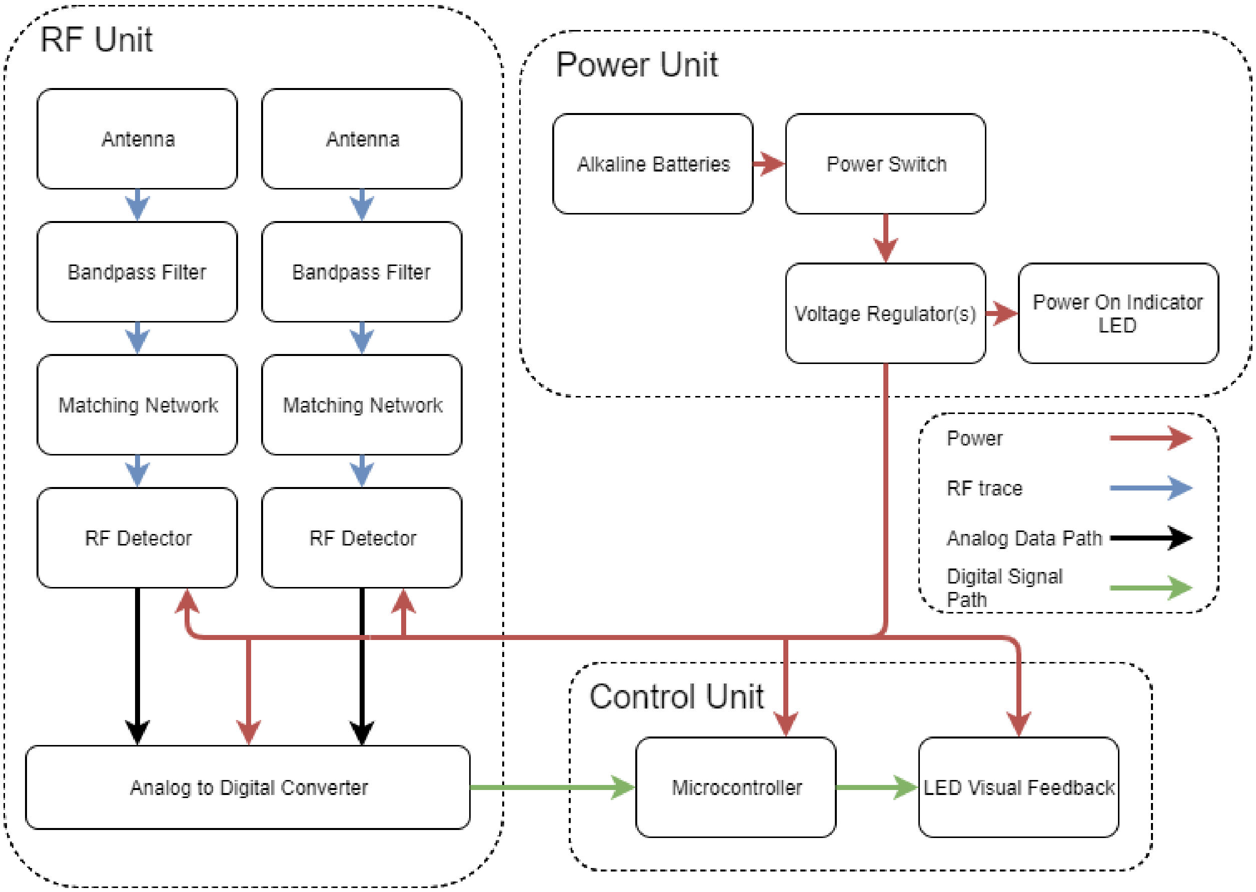

Figure 1: Block Diagram

2.1 Power Unit

The power unit will be in charge of feeding energy to the device for any period of time that it is needed.

2.1.1 Alkaline Batteries

In order to make this device easy to use for a long time, we will use Alkaline batteries. We have not finalized our choice of micro-controller or RF detectors, however these typically operate for a range of voltages. A supply of 3.3 V should be sufficient, so three AA or AAA batteries will be able to keep that fully powered. The microcontroller, RF detectors, and LEDs collectively use less than 50 mA of current, so using alkaline batteries will be adequate [3]. The device will only be used in short bursts throughout the day. If the lifetime is around 10-20 hours, this will provide two to four months of use at ten minutes per day.

Requirement 1: Batteries need to supply up to 50 mA to the system for a voltage range of 3.3 to 4.7 V.

Requirement 2: Batteries should be easily accessible so as to be replaceable.

Requirement 3: The batteries should provide a lifetime of 10-20 hours of use.

2.1.2 Voltage Regulator

This circuit will ensure the proper power levels are delivered to each system.

Requirement: Supply a constant 3.3 V $\pm 5\%$ for use by the microcontroller, RF detectors, and ADC.

2.1.3 Power Switch

This device does not need to run continuously. We will have a switch to power it on and begin detecting. Once groups have been scanned for RF interference, it can be switched off to keep batteries alive as long as possible.

Requirement: The power switch should be easily accessible and rigid enough to avoid accidental flipping.

2.1.4 Power On Indicator LED

This will be a small LED that will be in series with the power switch to indicate if the device is on or not. This is to ensure that users will not mistakenly leave it on for extended periods of time unnecessarily.

Requirement: The LED must be visible when being held by the user and must consume less than 15 mA.

2.2 RF Unit

The RF unit will be responsible for the reception, filtering, and power measurement of the desired RF signals. The device needs to detect signals from approximately one meter away, which is close enough to capture the high power transmission from cell phones, so amplification of these signals is not needed. The frequency bands of interest [2] are listed in Table 1. From these frequencies, we can choose two larger frequency bands which will capture all of the individual bands. Table 2 lists the frequencies of the two bands for which we will design the RF receive paths.

Technology	**Frequency (MHz)**
GSM 850	824.2-848.8
GSM 1900 (PCS)	1850.2-1909.8
UMTS B2 (1900 PCS)	1850-1910
UMTS B4 (1700/2100 AWS 1)	1710-1755
UMTS B5 850	824-849
LTE B4	1710-1755
LTE B13	777-787
LTE B17	704-716
LTE B25	1850-1915

Table 1: Frequency Bands of Cellular Phones in Puerto Rico

Band	**Frequency (MHz)**
Lower	704-849
Upper	1710-1915

Table 2: Frequency Bands of Receive Paths

2.2.1 Antennas

The antennas will detect the radio frequency interference coming from cell phones. These will be purchased devices.

Requirement 1: The antennas must pick up frequencies 704-849 and 1710-1915 MHz.

Requirement 2: The antennas should have an impedance of 50 ohms ±25% so that no matching network is required at the input of the bandpass filters. If this is not possible, matching networks can be added.

Requirement 3: The antennas should have greater than 40% efficiency so that received signals are not degraded beyond detection capability.

2.2.2 Bandpass Filter

Two bandpass filters will be designed for detection of the two frequency bands listed in Table 2. They must be low loss so the received signals remain above the detection threshold of the RF detector.

Requirement 1: Less than 5 dB of loss within the passband.

Requirement 2: Must provide greater than 20 dB of rejection in the stop band.

2.2.3 Matching Network

Two matching networks will be implemented for optimal power transfer between the bandpass filters and the RF detectors. The RF detector will have different input impedances for each frequency bands, so the matching networks will be designed differently for each frequency band.

Requirement: The matching networks will convert the impedance of the RF_{in} port of the detector to 50 ohms ±25% over the two frequency ranges.

2.2.4 RF Detector

The RF detectors will measure the power of the received RF signals. The detectors will measure signals above a threshold of -20 dBm, which will effectively avoid detecting background signals from WiFi and downlink cell signals. Each detector will output a voltage relative to the input signal, which can then be used to determine the received power.

Requirement 1: The detectors must be able to measure signals with frequencies at 704-1915 MHz.

Requirement 2: The detectors must detect signals with input powers between -20 dBm and 10 dBm.

2.2.5 Analog to Digital Converter

The ADC will be used to convert the output of the RF detectors to a usable digital scale for measured power. This will likely be integrated in the microcontroller.

Requirement 1: The ADC must be capable of converting the output of the RF detector to a usable digital scale with at least 8-bit precision.

Requirement 2: The ADC should have multiple inputs to handle both outputs from the RF detectors.

2.3 Control Unit

2.3.1 Microcontroller

The microcontroller will be used to analyze the data from the ADC, which will tell us if a cell phone has been turned off or not. We will set a threshold for signal strength to determine if a phone is transmitting. The microcontroller will also be responsible for controlling the visual feedback LED, which alerts the user to the presence of a phone.

Requirement 1: Must be easily programmable and handle the data from the ADC (which may be integrated in the microcontroller).

Requirement 2: Must have at least two GPIO pins for controlling the detection LEDs and provide a minimum of 10 mA to each.

2.3.2 LED Visual Feedback

We will have two different colored LEDs that act as the visual feedback for the user of our device. These will be controlled by the microcontroller.

Requirement 1: Must be visible while user is holding the device.

Requirement 2: Each LED must consume less than 15 mA.

2.4 Risk Analysis

We believe that the bandpass filters pose the greatest risk to the completion of the project. The bandpass filters must be accurate enough to only capture the frequency bands we need. If they detect frequencies out of this range, they could potentially show false alarms. If they do not pass the desired signals, then we will not be able to determine if cell phone interference is present. They also need to have minimal loss so we can detect low-strength signals. Bandpass filters can be difficult to design for specific center frequencies and bandwidths. They are susceptible to parasitic capacitances and inductances, which can affect the frequency response. They must be carefully designed and simulated so that they provide the performance we need.

3 Ethics and Safety

3.1 Ethics

Our device is simply an RF receiver, however it does contain an antenna, so it is important not to radiate power unnecessarily. Devices with clocks, such as the microcontroller, can produce radiation, so it is important to have adequate isolation between this component and the antenna. Our device must comply with Title 47 of the Code of Federal Regulations §15.5 [4].

3.2 Safety

There are several safety concerns for this device, and according to the IEEE Code of Ethics, we are responsible for making our device safe for the user [5]. Since the device is portable, it will be kept near or on a person, therefore the device needs to operate safely and not cause physical harm to the user. This means that it should not overheat or shock anyone who is using the device. For electrical protection, the case should be made so that all electrical circuits or wires are concealed. This will protect the user and the device itself. The current in the device should be controlled to avoid overheating. Since alkaline batteries have the potential to leak, the device should be sealed to protect the user should this occur.

References

[1] Lnn S, Forssn U, Vecchia P, et al Output power levels from mobile phones in different geographical areas; implications for exposure assessment Occupational and Environmental Medicine 2004. [Accessed: 21-Sep-2017]

[2] “Puerto Rico Wireless Frequency Bands and Carriers.” FrequencyCheck, www.frequencycheck.com/countries/puerto-rico. [Accessed: 21-Sep-2017]

[3] “Battery Capacity.” Techlib.com, www.techlib.com/reference/batteries.html. [Accessed: 21-Sep-2017]

[4] “General Conditions of Operation.” Code of Federal Regulations. Title 47 Chapter I Part 15.5.

[5] IEEE.org. (2017). “IEEE Code of Ethics.” [online] Available at: http://www.ieee.org/about/corporate/governance/p7-8.html [Accessed: 21 Sep. 2017].