

# Small rotor-craft obstacle avoidance imaging radar

DESIGN DOCUMENT

SDMAY21-07

Dr. Mohammed Tayeb Al Qaseer

Felipe Varela Carvalho – Signal Processing

Matthew Bahr – Antenna Design

Matthew McDermott – Circuit Design

Leonardo Bertocello Machado – Circuit Design

Michael Ostrow – Microcontroller Programming

Joshua Welton – Microcontroller Programming

[sdmay21-07@iastate.edu](mailto:sdmay21-07@iastate.edu)

# Executive Summary

## Development Standards & Practices Used

- Software practices/standards:
  - Frequency analysis - IEEE 1597.1
  - Software development - ISO 9000 (Agile)
- Circuit practices/standards:
  - Voltage Regulation - IEEE C57.15
- Hardware practices/standards:
  - Antenna and Propagation - IEEE 211 & IEEE 145
  - Measuring Electromagnetic Field Strength - IEEE 356

## Summary of Requirements

- Design and optimization of passive antenna(s)
- Design of power supply and voltage regulators
- Design of RF emitters and receivers
- Programming of ADC and microcontroller
- Signal processing and data presentation

## Applicable Courses from Iowa State University Curriculum

	Electrical Engineering	Computer Engineering	Computer Science
100 level	185	185	
200 level	201, 224, 230	281, 288	207, 227
300 level	303, 324, 311, 333		
400 level			

## New Skills/Knowledge acquired that was not taught in courses

- RF circuit design
- Frequency optimization for Antenna implementation
- Image processing in Python
- Voltage regulator design
- Radar technology principles

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# 1 Introduction

## 1.1 ACKNOWLEDGEMENT

The completion of this project would not have been possible without the assistance of many people. Specifically, the group would like to thank the following:

The Electrical and Computer Engineering Department, the Electronics and Technology Group, and Iowa State University, thank you for the invaluable help and learning opportunities you have presented each member of this group with throughout each member's college career. Thank you for providing materials towards the completion of the project and for giving the team a space in which to collaborate on the project.

To Dr. Mohammad Tayeb Al Qaseer whose knowledge and expertise has provided the group with countless learning opportunities and experience.

Thank you again to all those who have aided the group throughout this project.

## 1.2 PROBLEM AND PROJECT STATEMENT

When flying any type of vehicle, it is imperative to avoid any collisions with other objects. One of the most dangerous objects that a flying vehicle could hit are overhead power lines and guywires. These wires are capable of not only damaging the craft but also causing large amounts of damage through fires. Even though these wires can be quite dangerous, it is difficult to see these wires in everyday conditions.

To avoid potential collisions, a proof-of-concept system will be developed that utilizes radar operated antennas to detect and visualize wires and their orientations relative to the vehicle. This radar system will be comprised of a combination of circuitry and programming that will allow an antenna to find and visually recreate a wire's location and orientation for an operator. At the end of this project, we will have a proof-of-concept prototype system that can successfully locate a wire and visually recreate it at a computer that is connected to our radar system. This visual recreation should contain enough information so that an operator would know how to avoid the wire with their vehicle.

## 1.3 OPERATIONAL ENVIRONMENT

Since this product will be used to locate wires that are normally difficult to see, this product will be required to operate at most outdoor conditions. Specifically, the finished product will be able to operate in both dusty and foggy conditions and must also be able to operate at any time of the day. This solution assumes that an operator will not operate under extreme weather conditions.

## 1.4 REQUIREMENTS

This project has a set of functional, environmental, and non-functional requirements but, due to the nature of this project being a preliminary proof-of-concept, our project does not have a specific economic requirement.

Functional requirements include:

- Being able to detect overhead lines that are 10-100 meters away.
- Sending antenna radar data to a PC.
- Generate a visual diagram of the size and orientation of the overhead lines to be viewed and understood by an operator.

Non-functional requirements include:

- Sampling the antennas at a minimum of 100kHz and to an accuracy of 16 bits to ensure accurate and sufficient data.
- Utilize a phase-locked loop to control the frequency throughout the circuit.

Environmental requirements include:

- Detecting overhead lines in most non-extreme weather conditions

## 1.5 INTENDED USERS AND USES

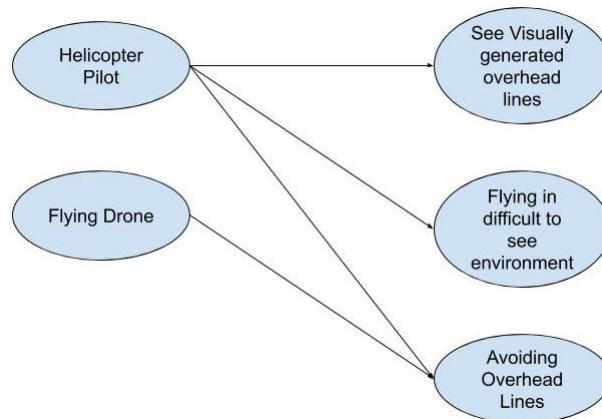


Figure 1: User-Use case diagram

The radar system is intended to be used by any company or individual that would like increased security or situational awareness while flying a vehicle or craft. The use of this project would be for a remote-controlled aircraft to be able to detect small wires and other objects that are either too small to detect by camera or if there are visibility reducing weather conditions.

## 1.6 ASSUMPTIONS AND LIMITATIONS

### Assumptions:

- Range of RADAR will be 10-100 meters
- Using a modified horn antenna
- Will use 24 GHz operating frequency
- Will use pc to process data and images

### Limitations:

- Due to COVID-19, no in person meetings will be conducted during the Fall semester, and possibly the Spring
- Research and Development will have a budget of up to \$500 without special permission from the department
- Antenna will initially be constructed with 3D printer material, so structural integrity might be reduced compared to an aluminum antenna

## 1.7 EXPECTED END PRODUCT AND DELIVERABLES

The expected end product will be a prototype system that will act as a proof-of-concept of the described technology. The product will include the following deliverables:

- A set of horn antennas together with integrated technology to detect wires from 10-100 meters away.
- A set of integrated circuits such as a radio-frequency circuit, power regulators, analog-to-digital converters, and a microcontroller) which will be combined into a single printed circuit board.
- Code for a computer to take the radar data as an input and outputs a visual that an operator could use to see the detected wires.
- Design documentation to be used by following engineers and researchers who work on improving and moving this problem forward.

The prototype system and other deliverables will be ready April 2021.

## 2 Project Plan

### 2.1 TASK DECOMPOSITION

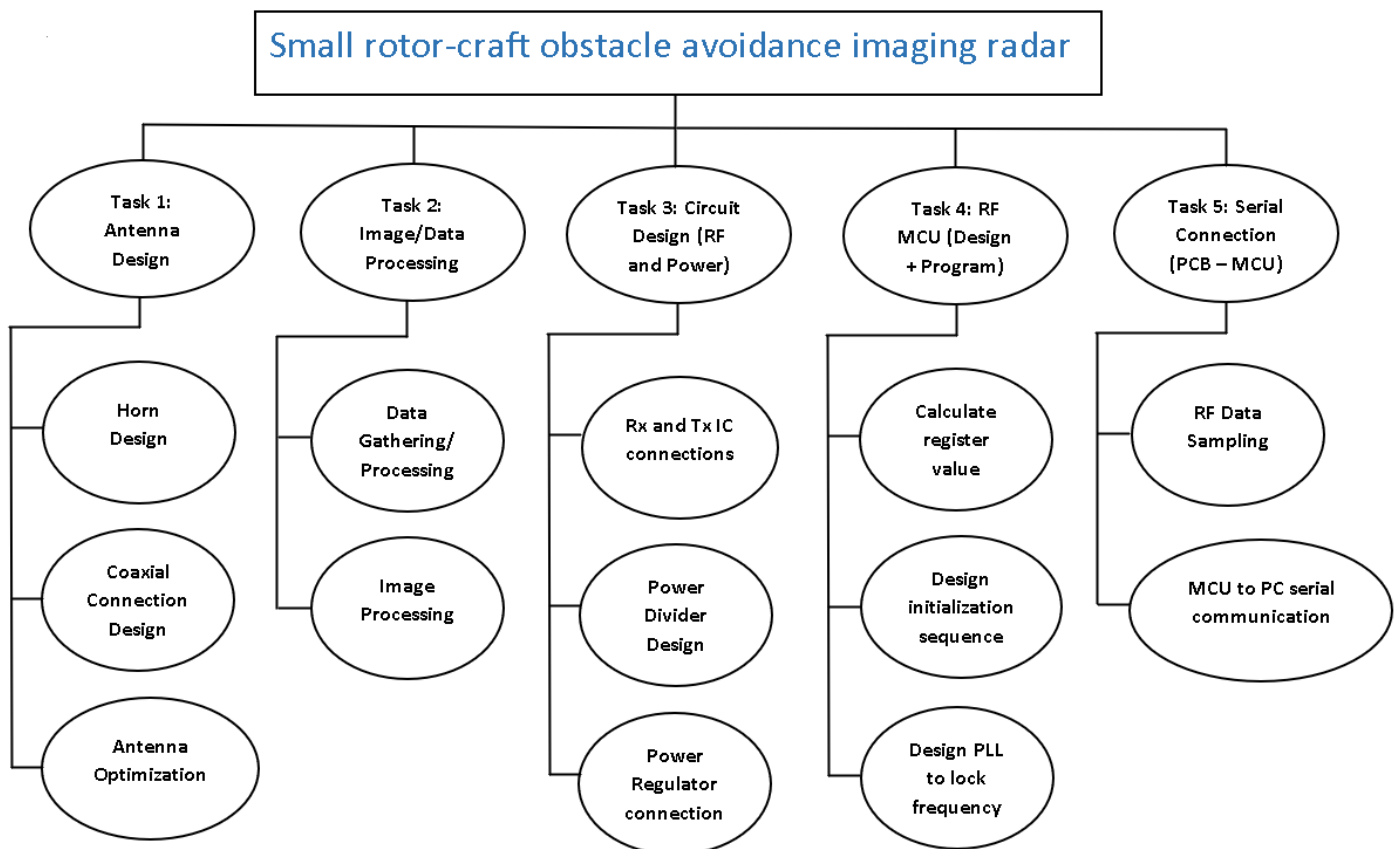


Figure 2: Task decomposition table

### **Task 1: Antenna Design**

Antenna design will be done through CST Studio. The design of the antenna has already been completed beforehand, so the main amount of work will be done to optimize the antenna design through CST.

### **Task 2: Image/Data Processing using Python**

Development of algorithm to interpret data coming from the microcontroller and retrieving meaningful information from it. The goal is to be able to identify the following parameters with the given data: orientation and location.

Also, develop an image of the expected powerline overlaid with an original image of the powerline location.

### **Task 3.1: Circuit Design - (Power Supplies/Regulators and ADC)**

As seen in the block diagram, the power supply/regulators will provide power to almost every component in the radar system. It is crucial to have a variety of voltages to supply since each component's requirements may vary. Circuit design will be done through Altium Designer.

ADC implementation will also be carried out in Altium Designer and will feed data from RF receiver (task 3.2) to microcontroller.

### **Task 3.2: (RF Circuit, Microcontroller – physical layout, pins, port connections)**

Design of 2 RF circuits: an emitter and a receiver. These will utilize the Antenna as part of the circuit in order to attenuate radio frequencies. Design will be done in Altium Designer.

Also, clear physical layout of pins and port connections will be decided upon at the end of this task.

### **Task 4: Design and program RF Microcontroller for specified parameters**

The RF Microcontroller will be programmed to the specifications need for the project, such as the operating frequency. There will also be phase loop locking to ensure that the microcontroller is operating at the correct frequency.

### **Task 5.1: RF Data Sampling**

A set of analog-to-digital converters will be needed to sample the RF circuits. This setup will then turn the analog values the sensors output into digital values the microcontroller will be able to read.

### **Task 5.2: Microcontroller to PC serial communication**

The microcontroller on the embedded system will communicate with the PC using SPI serial lines. The microcontroller will take data in from the radar system and will translate the information to the PC.

## **2.2 RISKS AND RISK MANAGEMENT/MITIGATION**

### **Task 1:**

The current plan for antenna fabrication is to use a 3D printer. This process may create an antenna that is not sufficiently sturdy or rigorous enough for the operations that we need. The risk factor for this is relatively low since the testing environment will be controlled enough to prevent any dangerous conditions for the radar system. The risk factor: **0.1**



Once the antenna has been constructed, we will be use conductive spray paint to coat the outside of the antenna. This paint may not be able to get down into the channels of the antenna thus potentially reducing the conductive capabilities of the antenna. Overall, the conductive spray paint should suffice but a risk factor of approximately: **0.2**

**Task 2:**

The current plan for the PC algorithm development and image processing is to use Python as the main language. Python has strong image processing libraries, such as OpenCV with convenient Python wrappings. However, there is a chance that Python does not support our desired tasks. If that happens, the group will use MATLAB and some already pre-defined algorithms to accomplish the desired tasks. Risk factor: **0.1**

When testing the algorithm, which will be designed before the system is completely built, there is a chance that the algorithm does not work as intended. If that is the case, the group will evaluate the situation and decide if the algorithm needs to be re-worked. Depending on the magnitude of the problem, the group will set a wider error margin and try to work from there. Risk factor: **0.2**

**Task 3:**

Power regulators are designed improperly thereby leading to an incorrect amount of power supplied to the circuit which causes damage to other existing components on the board. Risk Factor: **0.1.**

The RF design may prove faulty in early design stages and provide unreliable outcomes. This in turn will feed bad information to the microcontroller leading to incorrect detection for the radar system. The risk factor assigned to this task is around .30 since there exists ample literature on the subject for us to follow.

**Task 4:**

Electric noise can cause data to become inaccurate. External sources can cause false data if magnitude of the signal is great enough. Proper filtering, both digital and analog, can help mitigate interference of this sort. Risk Factor: **0.1**

**Task 5:**

An improper communication setup will be devastating to the outcome of the system as the PC would be unable to correct for any info found from the antenna, but with proper debugging this should not be a problem. Risk Factor: **0.1**

Another potential problem would be the lack of proper libraries to communicate between the python on the PC and whichever microcontroller we choose, although many have access to an assortment of SPI libraries. Risk Factor: **0.1**

### 2.3 PROJECT PROPOSED MILESTONES, METRICS, AND EVALUATION CRITERIA

Milestones	Metrics	Evaluation Criteria
Optimized antenna	The optimization must reach a certain threshold to for the antenna to be usable.	If the antenna can read up a wire from 10-100 feet, it passes evaluation.
PC-microcontroller communication	The PC must have the ability to receive data via SPI protocols from the microcontroller.	If a variety of messages can be sent by the microcontroller and received by the PC, the communication protocol passes evaluation.
PC data interpretation	The PC must be able to interpret the radar data from the microcontroller.	If the PC can take the received radar data and transform it into a readable package, the evaluation is passed.
Algorithm to visually represent data	The algorithm must output a visual representation of the data coming from the microcontroller and be able to overlay it with an image from a camera input.	If the data received from the microcontroller results in wires being represented where the wires are on the camera, the algorithm passes the evaluation.
Circuit generation	The power regulator, analog-to-digital, and radio frequency circuits must be generated into Altium Designer.	If the components can be added together and tested without error, the circuit passes the evaluation.
Circuit construction	The final circuit including all the prior components as well as the microcontroller must be constructed.	Many electrical and digital tests will be performed, but if the circuit can send proper radar data to the PC, the circuit passes evaluation.
Microcontroller-radio frequency circuit communication	The radio frequency circuit must send data to the microcontroller so that the microcontroller can process the data	If the microcontroller receives enough full data from the separate radar receivers, the microcontroller passes evaluation

Table 1: Table of Milestones

## 2.4 PROJECT TIMELINE/SCHEDULE

Below is the table containing the valuable information in the above Gantt chart:

# Project Planner

*Please only edit cells below*

ACTIVITY	Assigned To	Progress %	START DATE (m/d/y)	END DATE (m/d/y)
<b>Matt B</b>				
Optimize antenna through CST Studio		90%	10/5/20	11/25/20
Design coaxial cable connectors in CST Studio		50%	10/26/20	11/25/20
Aid with algorithm design for image processing		10%	11/1/20	11/25/20
<b>Felipe</b>				
Design and test python library for image processing (openCV)		100%	9/23/20	10/4/20
Aid with antenna desing		50%	10/4/20	12/30/20
Design flowchart for data annalysis algorithm		100%	10/7/20	10/12/20
Write software to test and fine tune flowchart		100%	10/12/20	10/20/20
Write software to read data from serial port		0%	11/1/20	11/20/20
Develop software for reading and interpreting data. Develop image processing algorithm		0%	11/20/20	3/1/21
<b>Josh</b>				
Research RF IC Chips and MIMO Antenna Control		100%	9/30/20	10/14/20
Design program for RF IC Chips for selected controller		75%	10/14/20	11/4/20
Test RF controller for functionality		0%	1/25/21	3/1/21
<b>Matt McD</b>				
Learn Power regulator circuit design		100%	10/5/20	10/12/20
Power Regulator Circuit Design		100%	10/12/20	11/25/20
<b>Mike</b>				
Choose Microcontroller and corresponding ADCs		100%	9/23/20	10/7/20
Write code to understand RF data		100%	10/8/20	11/1/20
Establish SPI serial and generate protocol		50%	10/8/20	11/1/20
Connect RF Data and Serial Protocol		50%	11/1/20	11/20/20
Calculate ADC Ref voltage circuit values		0%	11/19/20	1/1/21
Test connection between recievers and microcontroller		0%	12/20/20	1/14/21
<b>Leon</b>				
Study RF circuits from datasheets		100%	9/25/20	10/13/20
Design RF transmitter circuits in Altium Dsginer		90%	10/13/20	11/1/20
Design RF receiver circuits in Altium Designer		80%	10/13/20	11/1/20
Aid in the implementation of ADC/PCB		35%	11/1/20	12/18/20

Figure 3: Project Gantt chart planner individual tasks



## 2.5 PROJECT TRACKING PROCEDURES

For this project, the group members have decided on several different methods for project organization. The group will use Discord for communication between members, and it will also serve as the method to make announcements to the group. Cybox will be used for file storage for all non-code work. This will include drawings, schematics, important emails, and written documents. GitHub will be used for code storage. Finally, Microsoft Excel will be used for official scheduling and to keep track of progress made on the project.

## 2.6 PERSONNEL EFFORT REQUIREMENTS

The hours assigned to each task in the table below is based on a rough approximation. Each team member will be able to adjust their hours once they know the full scope of work required for their portions of the project.

Matthew Bahr	Antenna CST Studio Design – 20 hours
Leonardo Bertoncello Machado	Altium Designer – 30 hours
Matthew McDermott	Altium Designer - 30 hours
Michael Ostrow	Microcontroller Serial Communications –25 hours
Felipe Varela Carvalho	Algorithm development – 25 hours
Joshua Welton	RF Circuit Controller – 20 hours

Table 2: Effort requirement table

## 2.7 OTHER RESOURCE REQUIREMENTS

To complete this project, the group will require a 3-D printer along with the necessary material to use the printer. A microcontroller will be purchased as well. Various electronic parts will be used to create the circuitry needed for the project.

## 2.8 FINANCIAL REQUIREMENTS

Iowa State University’s College of Engineering has provided the group a budget up to \$500 to work with. The budget will cover all costs associated with the project including various parts and fees necessary to build the required components.

# 3 Design

## 3.1 PREVIOUS WORK AND LITERATURE

There are numerous predecessors to RF radar systems. One in which our initial design and understanding of the system is based on is Analog Devices’ EV-RADAR-MMIC2 board [1]. It utilizes the same RF components (Rx and Tx) that we intend to use and contains a phase-locked loop (PLL) system that would work optimally with our design. It also operates in the ISM (Industrial, Scientific and Medical) frequency band, not requiring any special license to operate.

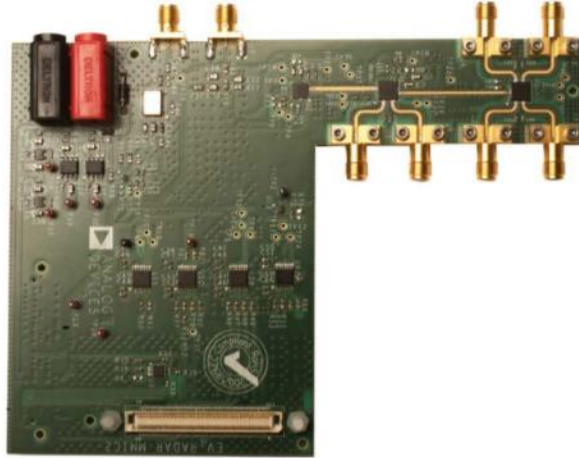


Figure 5: EV-RADAR-MMIC2 radio frequency chip

The benefits of following this system is that the high frequency it operates (24 GHz) allows for clear data points when attempting to scan a range of up to 100m. However, this PCB doesn't take into consideration orientation of objects, which in order to do so would require an additional Rx chip.

Another piece of research needed would be the ADC utilized for the radar system. For this we went with the Texas Instruments ADS88671DGSR. A 16-bit, 100-kSPS ADC [2] that fulfills the requirements.

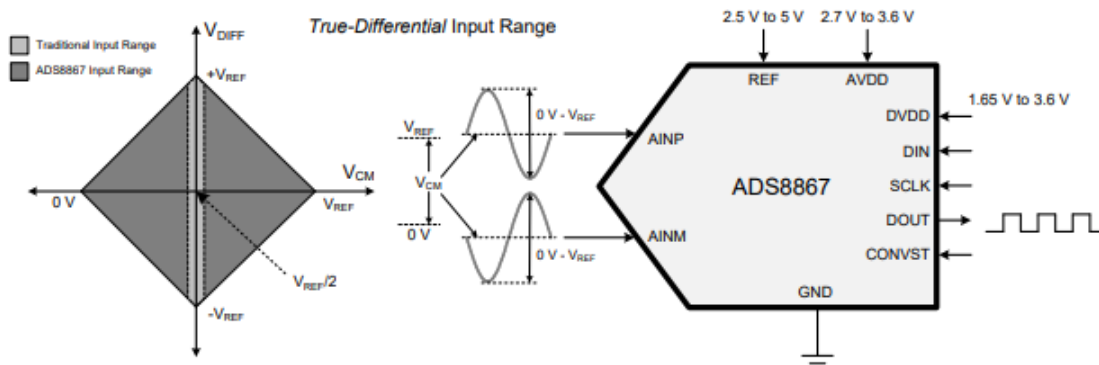


Figure 6: ADS88671DGSR analog-to-digital converter

What differentiates our design from what is available is seen on both hardware and software implementations. For hardware we are requiring the use of an additional receiver chip which will require an additional power regulator and a way to split the high-frequency line coming from the transmitter. For software, the team is writing proprietary software. Open-source libraries such as OpenCV are being used together with open-source referencing using websites such as Stack Exchange.

### 3.2 DESIGN THINKING

During the “define” phase of the design thinking process the group met with our advisor to discuss the requirements needed of our project. The main needs for the project are that a system is created to be used in aircraft for obstacle avoidance. The group decided to focus their effort on creating an integrated system that uses an

antenna to transmit and receive signals. The signals received by the antennas would then be sent through circuitry and then to a computer for use by the operator.

During the “ideate” phase, the group analyzed the individual sections of the project must be completed. Each section was analyzed by the group and different iterations of the original solutions were developed. The ideas that were generated for each section of the project are as follows:

Task	Potential Solutions
<b>Antenna Design</b>	<ol style="list-style-type: none"> <li>1. Do Antenna design using Inventor software and transfer it to CST Studio.</li> <li>2. Do the design through CST. This will require learning how to design through CST</li> </ol>
<b>Image Processing</b>	<ol style="list-style-type: none"> <li>1. Use MATLAB to accomplish this task               <ol style="list-style-type: none"> <li>1.1. Consider the libraries available for MATLAB regarding image processing</li> </ol> </li> <li>2. Use Python to accomplish this task.               <ol style="list-style-type: none"> <li>2.1. OpenCV is the industry standard for image processing in Python</li> </ol> </li> <li>3. Algorithm involving AI.</li> </ol>
<b>Circuit design and PCB layout</b>	<ol style="list-style-type: none"> <li>1. Use Altium Designer to construct/model necessary circuitry schematics.               <ol style="list-style-type: none"> <li>1.1 Use Altium Designer to correctly model PCB Layout after schematic.</li> </ol> </li> <li>2. Use Circuit Maker as an alternative for designing the circuit.               <ol style="list-style-type: none"> <li>2.1 Free alternative instead of using Altium Full Version for circuitry schematics.</li> </ol> </li> </ol>
<b>RF Circuitry</b>	<ol style="list-style-type: none"> <li>1. Use specified chips from the reference board denoted in 3.1</li> <li>2. Research various PLL, Receiver, and Transmission ICs that function with project requirements</li> </ol>
<b>Microcontroller Design</b>	<ol style="list-style-type: none"> <li>1. Which microcontroller to use               <ol style="list-style-type: none"> <li>1.1. Arduino</li> <li>1.2. TI MCU</li> <li>1.3. Raspberry Pi</li> </ol> </li> </ol>

Table 3: Solution table

### 3.3 PROPOSED DESIGN

Our design is an integrated circuit that utilizes a set of 10 radar cones (2 transceivers and 8 receivers). The functionality of this device will be to detect an exact distance and direction of incoming obstacles such as electric wires. It will do this by collecting the items distance from 8 different directions, and using these 8 directions, a PC will be able to calculate the locating of the obstacle. (**IEEE standards**). These 8 transceiver cones will be sampled at 100kHz per cone and that data will be sent through individual analog-to-digital converters. This digital data will then be sent to a microcontroller, which will process the data and send it to the PC to be used. The PC will then either avoid the obstacles itself or notify the machine operator.

### 3.4 TECHNOLOGY CONSIDERATIONS

**Horn Antenna:** A horn antenna made of aluminum will be used for signal transmission and receiving. The horn antenna has the ability to create signals that can reach anywhere from 10-100 meters. This antenna also narrows any signals that exit the horn. These narrowed, long-ranged signals will be able to detect any objects with much more precision than other antennas available. The main weakness of this approach is that the chosen material may impact the performance of the antenna.

**PCB (RF – PLL – Power Supply):** The printed circuit board containing all of the ICs will allow for streamline testing of appropriate power delivery and output signals from all components. However, since we are having to split a high frequency line between two receivers, this does open up the possibility of power loss if poorly designed. The trade-off in having to carefully designing a power divider for convenient and compact testing is worth it.

**Analog-to-digital converter (ADC):** This technology has the strengths to present the microcontroller the rf analog data to the microcontroller in a readable manner, by doing this however, we lose accuracy in rounding the analog value to a nearest binary. To minimize this issue, we used a 16-bit ADC. Another trade-off choosing an ADC with the minimum allowed sample rate (100kHz) in order to reduce the cost, and given a higher budget, a larger sample rate could be achieved.

**Raspberry Pi:** This component functions as the microcontroller for processing the incoming and outgoing data and to control the RF circuit. This component runs at 1.5GHz with 4 parallel processors allowing it to take in the high amount of serial data from the ADCs and then package it for the PC to use. A downside to this processor is the clock is not fast enough to supply many of the components and so remedied this by adding an external oscillator.

**Python programming language and OpenCV library:** As a high-level programming language, Python is a very versatile language with very intuitive commands and useful high-level commands. However, one of the downfalls of Python is that the language is naturally slow when compared to other languages such as C++. Another piece of technology that is used directly with Python is the OpenCV image processing library. OpenCV is a powerful image processing library and is considered to be the industry standard when it comes to Python. This library contains all the necessary commands to accomplish all of the required aspects of the project and much more. The tradeoff of using OpenCV is the fact that this is not as intuitive as using a specialized tool like MATLAB. MATLAB has a lot of specific commands that would simplify the code for the project greatly.

### 3.5 DESIGN ANALYSIS

Currently (10/25/2020) in the process of design, all IC's and components seem to function with each other with no glaring issues. This conclusion can be drawn by comparing datasheets and compatibility in voltages, power requirements and I/O.

As of today (10/25/2020) there is no need for modifications to the design. Once testing begins and complications are found, then reconsidering our design will come into play.



### 3.6 DEVELOPMENT PROCESS

The development process that the group has been following is the Waterfall method. We will use the Waterfall method due to progress on our project being sequential. The group collected all the requirements needed at the beginning of the semester and began working through them in a structured manner. The structured process includes working on each task at a time and then evaluating each completed task with the group.

### 3.7 DESIGN PLAN

Our use-cases boil down to obstacle avoidance, as a proof-of-concept. Hence in terms of requirements, we know that there will be a need for clear results on the antenna. The emphasis on proof-of-concept does lend itself to a more lenient design for modular application, meaning that our use-cases are limited to controlled testing and variable testing.

The requirements for the project are being taken care of through each subsection of the project. For the range requirement a modified antenna will be designed to reach the ranges and precision needed for accurate signal acquisition. The integrated circuits will be used to process the signals received from the antenna and these processed signals will then be sent to a PC for a user to interpret. Through these chosen designs, our use-case requirements will be met. We will be able to visually generate objects so that operators of aircraft can move around any objects to avoid collisions.

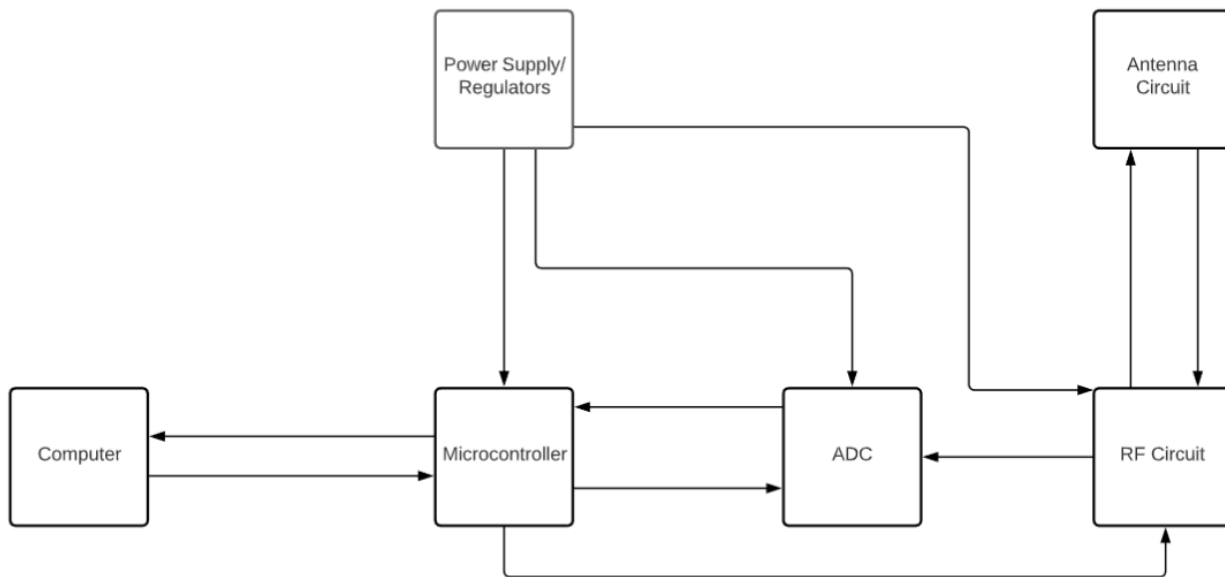


Figure 7: Circuit design flow chart

The modules seen below do hold a very abstract concept of how our systems will interconnect. However, it still shows the basic interactions that, despite complexity, increasing as we go to lower levels, they will remain the same. The further we go into design the clearer the interfacing becomes and the more specific components to fulfill these interfaces turn out.

## 4 Testing

### 4.1 UNIT TESTING

#### Unit 1: Horn transmission

Horn transmission will be tested within the CST Studio CAD. This is a powerful tool that allows the testing team to simulate various electric and magnetic field with different specifications. CST will be used to test the direction and intensity of the electric field that will be latter transferred into a voltage signal through a coaxial cable. CST provides a plethora of 3D and 2D maps that allows the testing team to make sure that the design will work correctly after it has been manufactured. The antenna needs to be able to have a 24GHz electric field output. Unfortunately, after the antenna has been manufactured, other than double-checking dimensions, there is no way to test it without connecting it with the other components.

#### Unit 2: Circuitry

The circuitry can be tested as a whole unit working simultaneously. The PLL IC can be tested by proxy by analyzing the Transmission IC. When connected to a spectrum analyzer via a coaxial cable and a dc block, the frequency that is being outputted by the Transmission IC should be shown on the analyzer, and this will ensure that both chips are working when this frequency is at 24 GHz. The Receiver IC can be tested by connecting a signal source through a dc block to a coaxial connector which is then connected to a receiver channel. This signal can then be measured by an oscilloscope by using test points tied to the outputs of each Receiver IC. We can also test the output of the voltage regulators by putting test points on the outputs of the regulators and checking voltage level and noise by use of an oscilloscope.

#### Unit 3: Analog-to-digital converter (ADC)

The ADC is necessary to make the values of the RF circuit readable to the microcontroller. The ADC does this by taking the analog output of the RF circuit as an input and outputs that number as a 16-bit binary fraction with the input as the numerator and a reference voltage as the denominator. To test this, a controlled reference voltage will be inputted as well as a controlled input voltage that is between the reference and 0V. To meet the non-functional requirements, testing will be done at 100kHz. The expected output will be read and calculated by hand. If the values match the ADC passes the test.

#### Unit 4: Microcontroller data processing

The microcontroller will be streamed a set of 16-bit binary values from 8 different receivers and must process this data into a package that can be then given to the PC. To test this unit, the microcontroller will be given a set of 8-16-bit numbers which the microcontroller will process and turn into a package in accordance with the microcontroller-PC communication protocol and output this package. If the outputted package includes all the inputted data and maintains the proper protocol, the method passes the test.

Once the Microcontroller passes this test, a second test will be performed. This test will be to test the non-functional requirement of sample rate. This test will be a repeat of last test except the microcontroller will be given 8 lines for data, each of them giving a new 16-bit number at 100,000 times per second. If the microcontroller can then output 100,000 properly formatted packages per second. The microcontroller passes the test.

#### Unit 5: PC data processing

The Python module will be tested individually to assure that there will be no problems coming from the software side of the project. Testing the algorithm will follow the unit testing philosophy. Each individual method will be

tested considering edge cases and overflow capabilities. To accomplish said tasks, testbenches are going to be designed to simulate the real-life application of the software and run through multiple use cases of the project.

At the end of the testing phase, the PC should be able to take information from a serial input and process it with the desired specifications. If the software can simulate a visualization of a power line and output the desired image on its own, it means that the software is ready to be integrated with the hardware.

## 4.2 INTERFACE TESTING

### Interface 1: Horn Antenna transmission to RF ICs

Testing this section will require access to an oscilloscope. We will inspect the RF circuit at the beginning from signal generation to ensure that the proper source signal is being sent through the circuit. We will also test at the end of the RF circuit to double-check the received modified signal from our antenna. Furthermore, the testing team will point the antenna at different objects and wires of different thickness at different distances.

### Interface 2: PLL IC with transmission IC.

The PLL IC will be outputting a sawtooth wave with a base frequency of 12 GHz to the REFin pin of the transmission IC. This frequency is very important because the frequency of the output electromagnetic wave is dependent on this reference frequency created by the PLL IC. To test this interface, we will need to display the output waveform of the PLL on an oscilloscope to ensure that it is the correct amplitude and frequency.

### Interface 3: Receiver IC to analog-to-digital converter (ADC)

The connection between the receiver and the ADC is crucial to allowing the microcontroller to read and interpret the incoming data from the RF circuits. To test these, we will be setting both the ADCs and the receiver ICs to the same reference voltage and then we will give the receiver-controlled radar values. To understand the intended ADC output, we will calculate what binary value would come out of the receiver by finding the binary fraction relative to the reference voltage. We will then read the actual output and if they are the same value, the interface passes examination.

### Interface 4: Microcontroller to PC communication

In this project, it is crucial that the output of the microcontroller is received by the PC with little to no noise. This will be tested in two ways. The first one involves outputting simple data from the microcontroller and testing the communication between both components. The data received by the PC should be very close to or the same as the data sent by the microcontroller. This will test the reliability of the communication and data accuracy.

The second test will involve getting the information from the microcontroller just like the first test but applying simple data manipulation on the PC side and see if the data changes as expected. This will test data typing and data manipulation reliability.

Furthermore, the testing team will point the antenna at different objects and wires of different thickness at different distances. Data is expected to be consistent.

## 4.3 ACCEPTANCE TESTING

### Functional:

- Detect overhead lines that are 10-100 meters away: To demonstrate that this function is working, the testing team will take physical measurements and translate it to the output of the software running on the PC side. The physical measurements either been distance from wire to antenna or wire direction, need to correlate to the PC output data. The client is unlikely to be included in this testing phase.
- Sending antenna radar data to a PC: Through the many interface tests, we are testing the ability of the RF data to transfer from the antenna to the PC. If all these component interfaces pass their respective tests,

then a final test will check the completed chain of components. The client is unlikely to be included in this testing as there is little to no variability into whether this works or not.

- Generate a visual diagram to be viewed and understood by an operator: This testing will make sure that the visual output of the software is easy to understand and outputs the correct information. This will require all of the components and software to be properly working. The client will be directly involved in this testing phase. Given that the output values are correct, the client will be the one deciding if the visual output and diagrams are acceptable and ready to be shipped as the final product.

#### **Non-functional:**

- Sampling the antennas at a minimum of 100kHz and to an accuracy of 16 bits to ensure accurate and sufficient data: The ADC and microcontroller are tested at 100kHz to ensure they are fit for running at the speed of the final project. The client gave us this specification and will not need to be included in more depth on the specification.

#### **Environmental:**

- Detecting overhead lines in most non-extreme weather conditions: This will avoid collisions with high-voltage lines, possibly avoiding electric fires and sparing any damages to nearby foliage.

## 4.4 RESULTS

For this project, each component must be designed and then fabricated separately. Due to this, testing cannot fully begin until our designed components come back to us. The group is anticipating that the components will be sent to us sometime in Spring 2021. During this time, extensive testing will be carried out to ensure all components work both individually and separately.

In the event of a component failing during the testing period, a list of items that can be purchased will be created as a backup. This list will serve as a safety in the event of a failure of one or more components.

## 5 Implementation

During next semester, the focus for the project will be on constructing a proof of concept of the physical radar system and integrating it with the necessary software. This implementation plan will be carried out in two stages, both happening around the same time.

The first stage will be to test the hardware that was designed during the first semester. This hardware includes the antennas, power regulator circuits, and RF circuits. The circuit designs will be used to construct a PCB board which will connect to the antennas that were optimized this semester. Each circuit will be tested independently to ensure proper performance is obtained. Once each individual component has been tested, integration between the remaining hardware will be done and tested.

The Second stage will involve developing software for the microcontroller to initialize the entire PCB and then control the flow of data from the chip to the PC. A second software will be developed for the PC to take flow of data and overlay the obstacles that are detected by the radar system. Once these programs are completed, they will be thoroughly unit tested.

Once both of these stages are complete, the group will begin working on integrating the two stages together to form the overall radar system. Testing will be done to ensure that the integration was done properly. Once this testing is finalized, the radar system will then be ready to meet the requirements of the project.

## 6 Closing Material

### 6.1 CONCLUSION

The work done by the group for this semester consists of optimizing a given antenna design to meet given specifications, designing circuit schematics for both power regulator circuits and RF circuits, microcontroller selection and the necessary initialization and optimization, calculating RF IC register values, and researching how to create a program using Python that can interpret and process the results obtained by the antenna.

The goal for this project is to create an obstacle avoidance radar system for use in small aircraft. This radar system will be used to detect power lines which normally go unnoticed when moving at high speeds. These detected power lines will be visually recreated for an operator to see and this operator will be able to use this information to maneuver the craft around the lines, thus avoiding any collision that may cause damage or injury.

Our plan of action is to continue working on our radar system by making improvements to the designs that we have already completed. We will use these designs to create both the antennas and the PCB needed for the radar system. Once we have the hardware created, testing will be done to look for any issues and the software side of the project will begin integrating the hardware together. This plan of using a combination of antennas, circuits, and software will allow the radar system to remain compact while also being able to be tested easily during the construction phase. This ease of testing will allow the group more flexibility in how the project is handled in the coming semester.

### 6.2 REFERENCES

#### 6.2.1 Evaluation Board

[1] A. D. Inc., "EV-RADAR-MMIC2 Analog Devices Inc.: RF/IF and RFID," Digi Key, 2017. [Online]. Available: [https://www.digikey.com/en/products/detail/analog-devices-inc/EV-RADAR-MMIC2/6072228?utm\\_adgroup=xGeneral](https://www.digikey.com/en/products/detail/analog-devices-inc/EV-RADAR-MMIC2/6072228?utm_adgroup=xGeneral). [Accessed: 15-Nov-2020].

#### 6.2.2 Datasheets

[2] T. I. Co, "ADS8867IDGSR ACTIVE," Texas Instruments, 2013. [Online]. Available: <https://www.ti.com/store/ti/en/p/product/?p=ADS8867IDGSR>. [Accessed: 15-Nov-2020].

## 6.3 APPENDICES

### Appendix A Definitions

RF – Radio Frequency

IC – Integrated Circuit

PCB – Printed Circuit Board

CST Studio – CAD design software for antennae

SPI – serial peripheral interface

PLL – Phase-locked Loop

### Appendix B Design Schematics

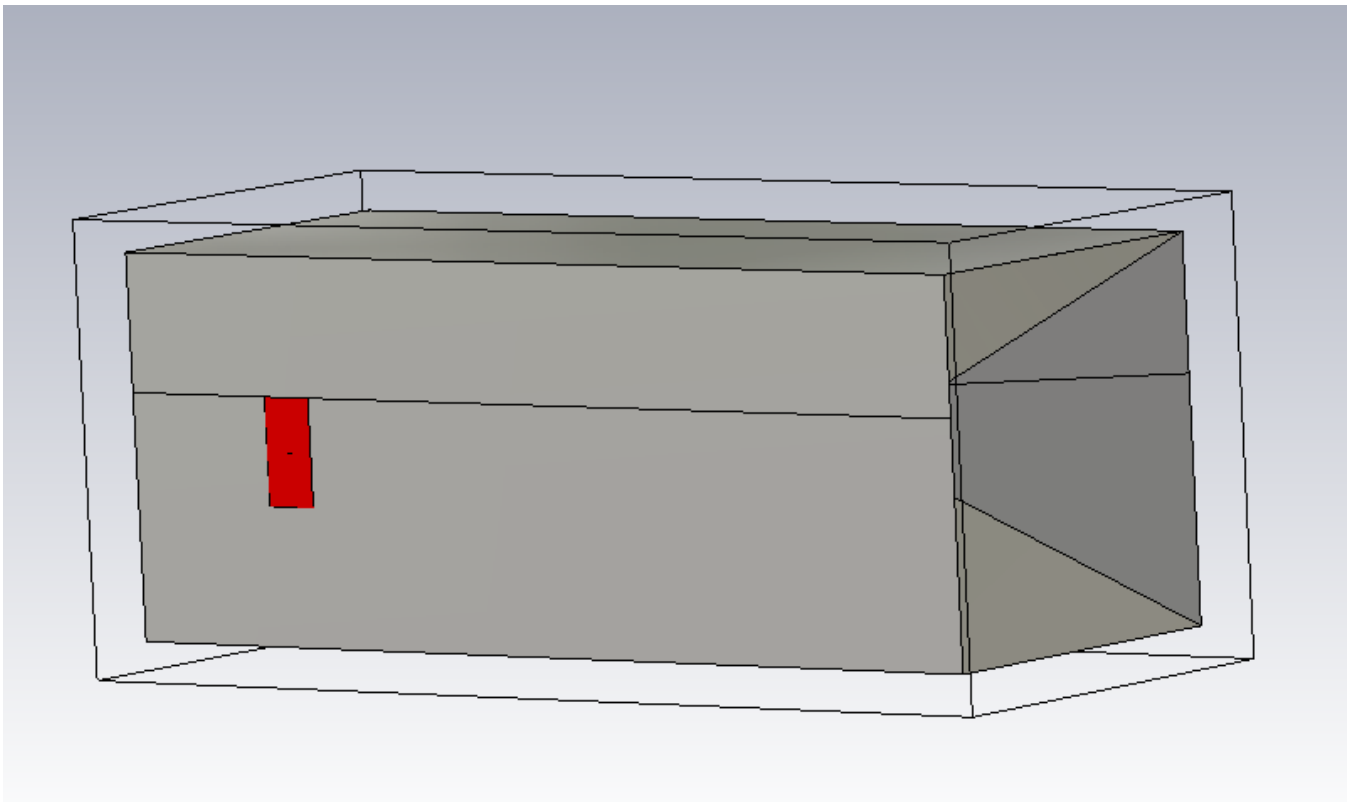


Figure 8: Antenna 3D Model

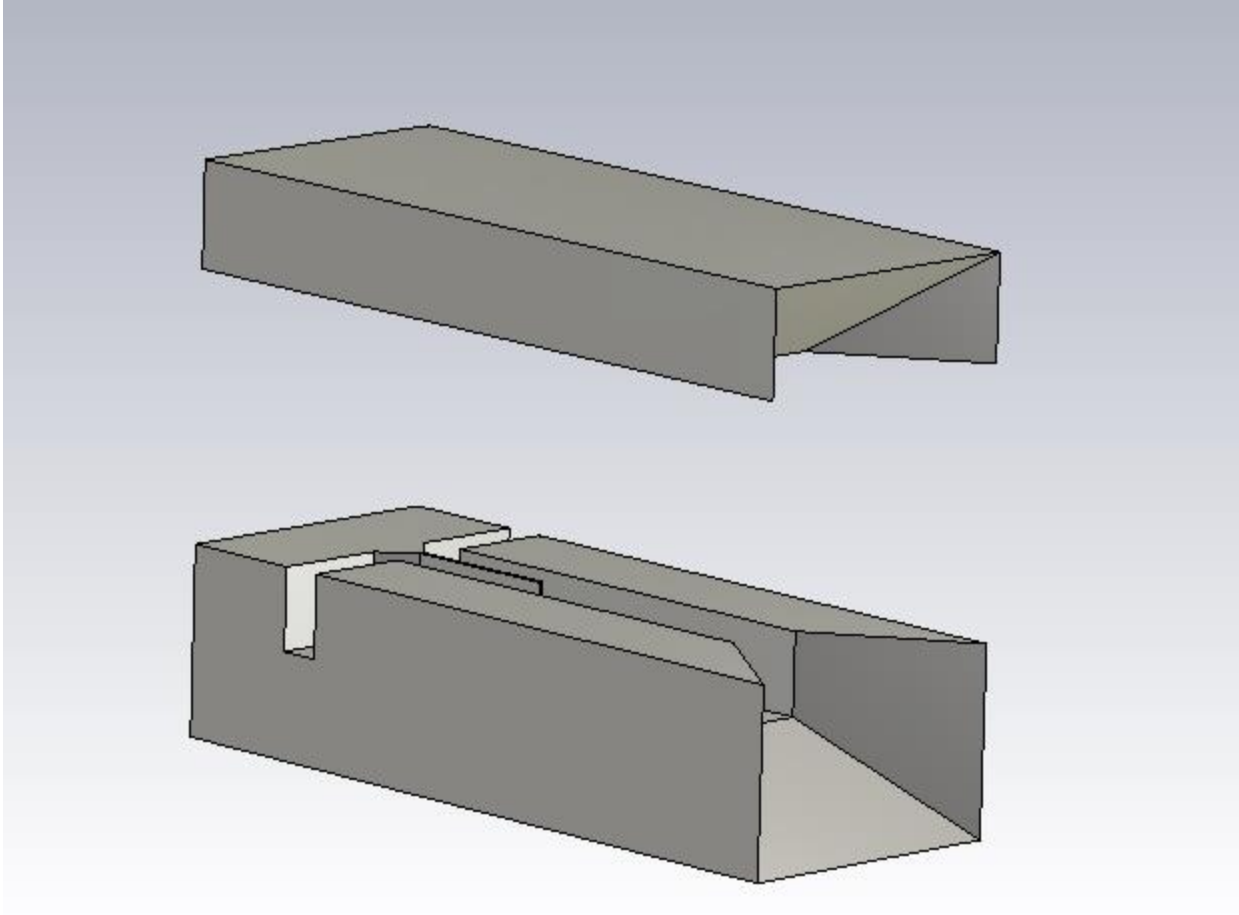


Figure 9: Antenna 3D Model Stage View

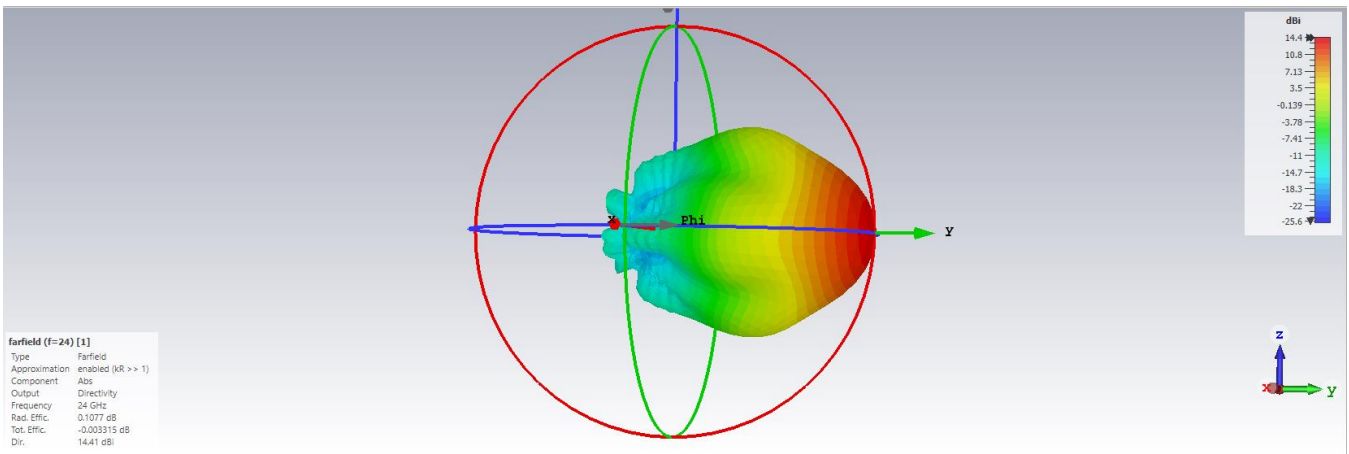


Figure 10: 24 GHz Farfield Propagation

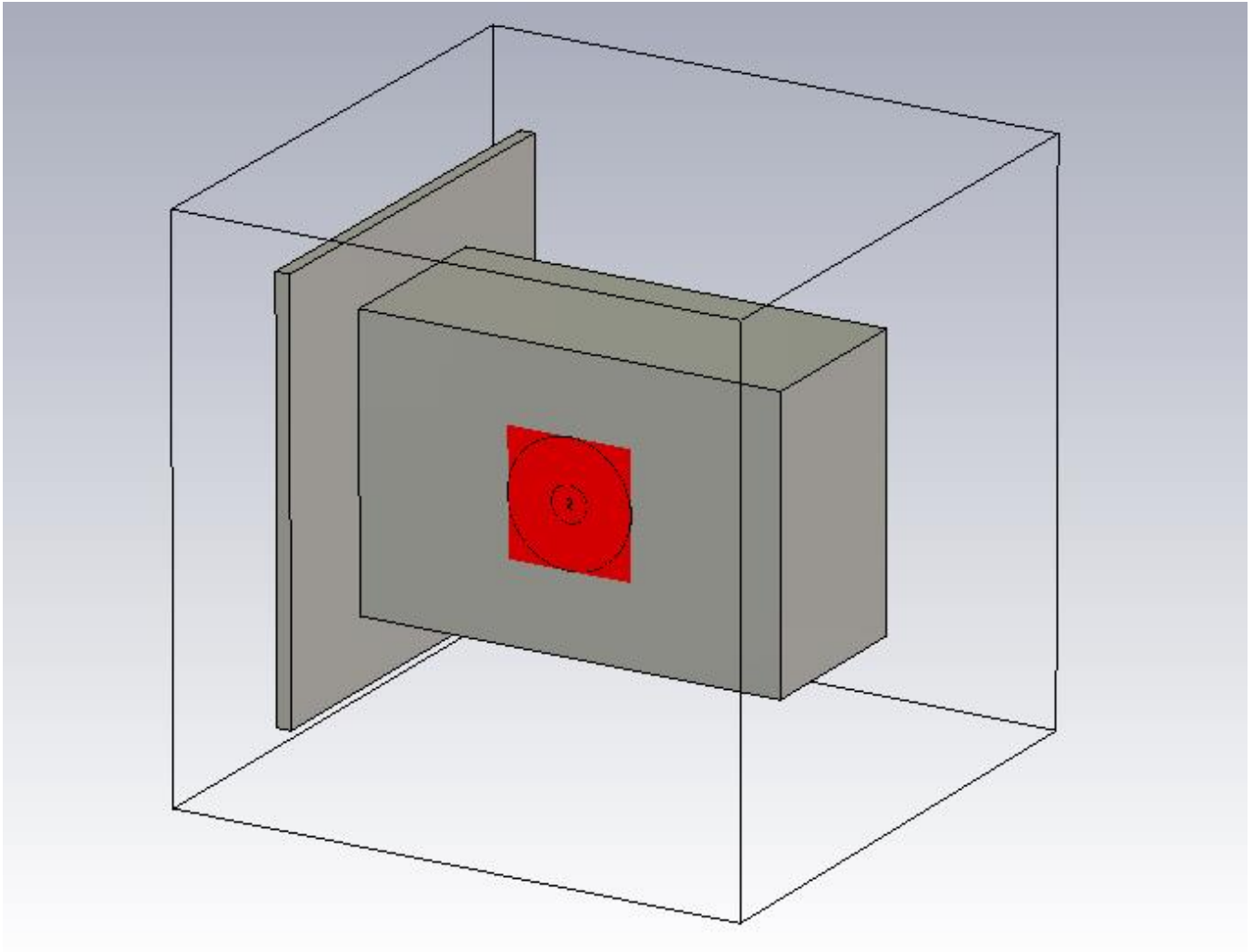
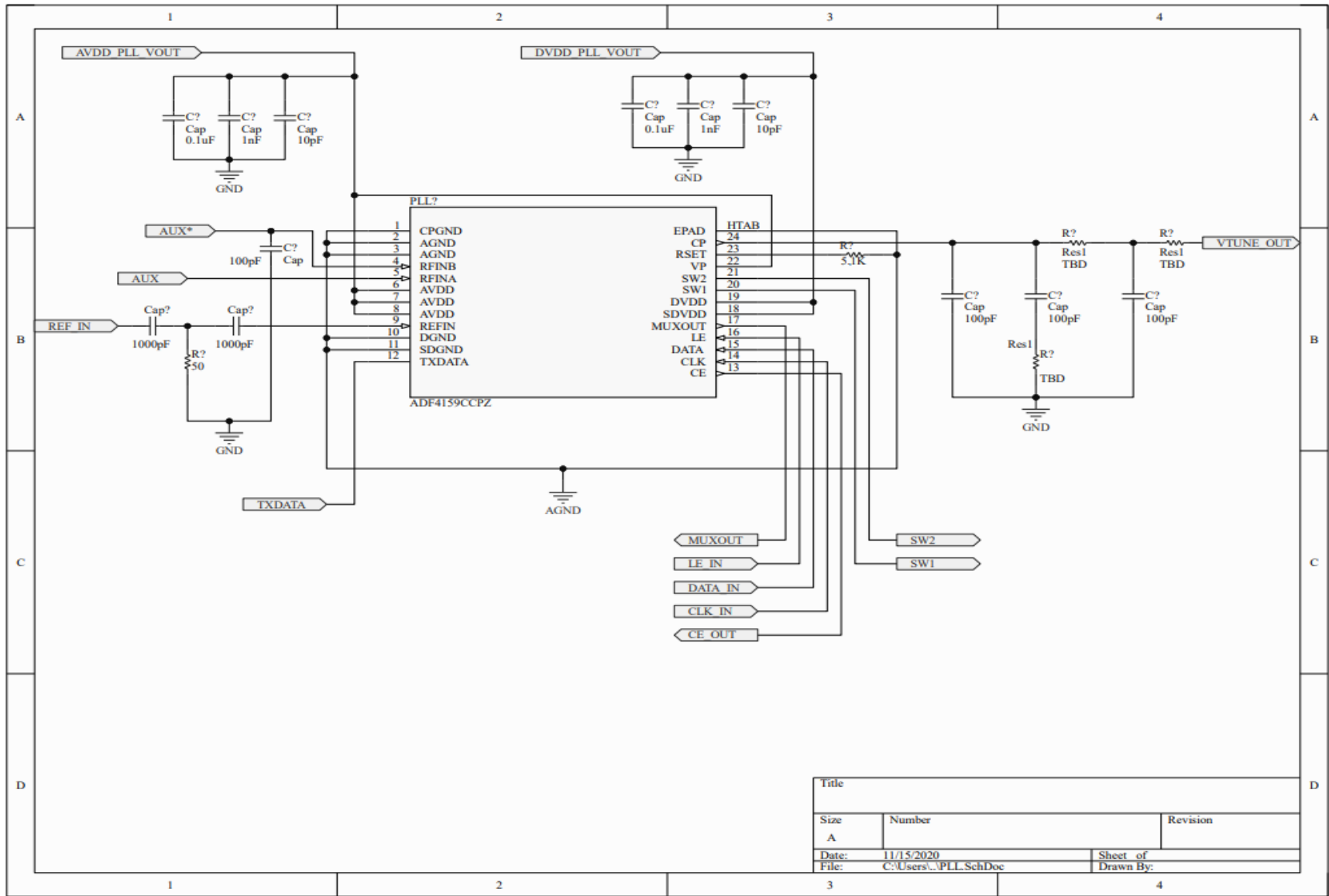


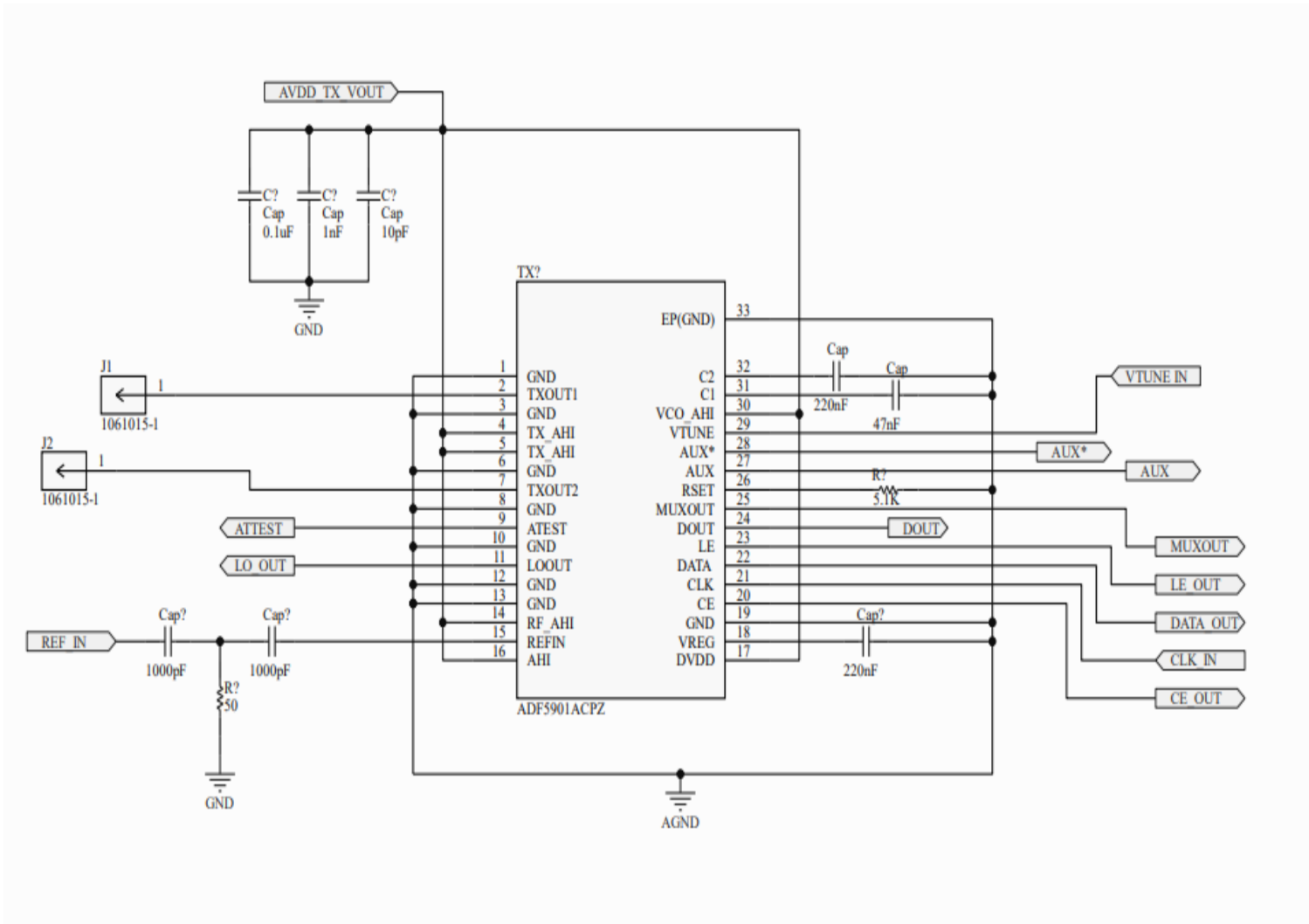
Figure 11: Coaxial Cable Connector Waveguide 3D Design



Appendix C: PLL, Transmitter, Receiver and Power Supply Schematics



Figures 12: PLL Circuit schematic



Figures 13: Transmitter Circuit Schematic

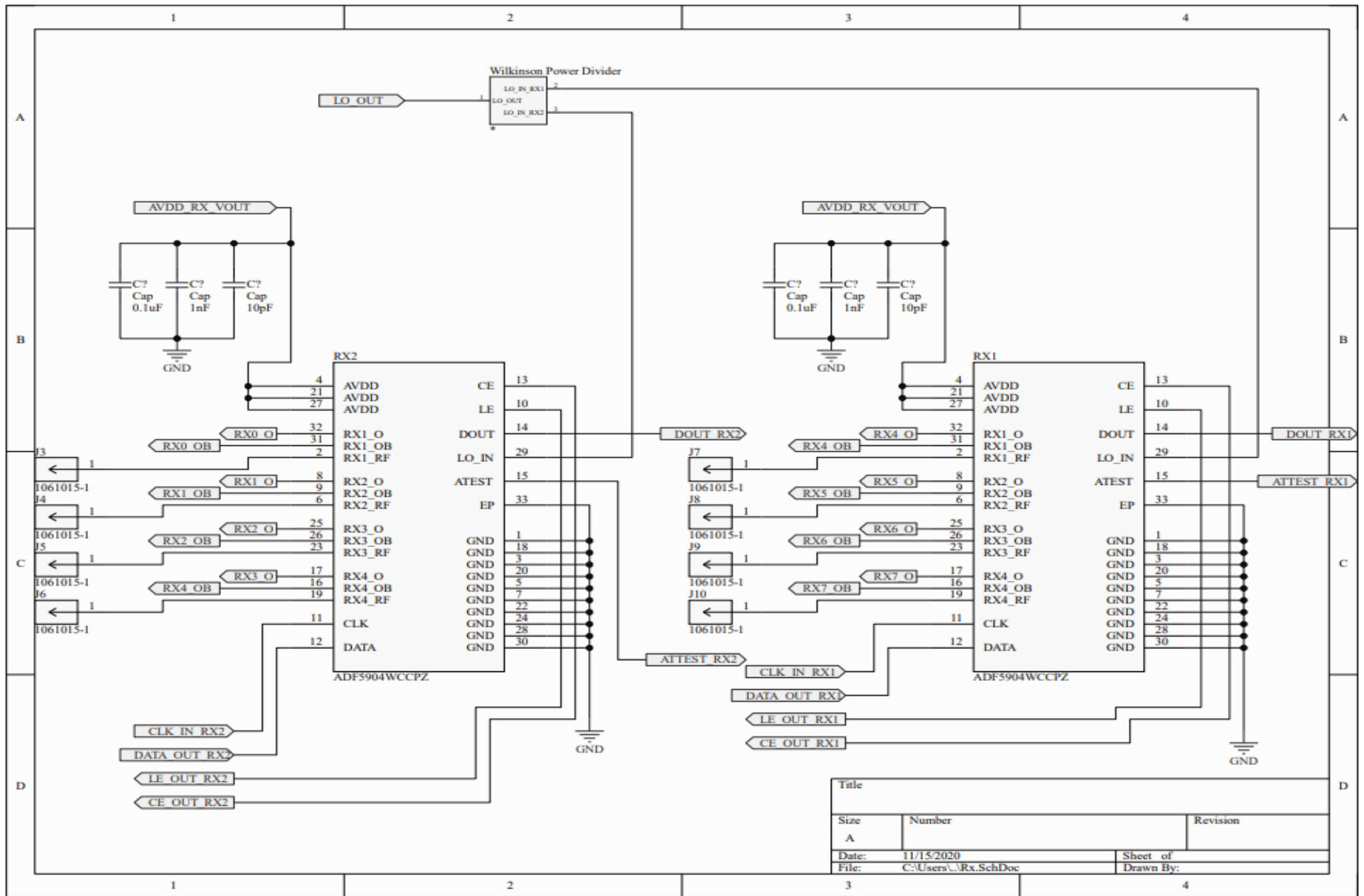


Figure 14: Receiver Circuit Schematic

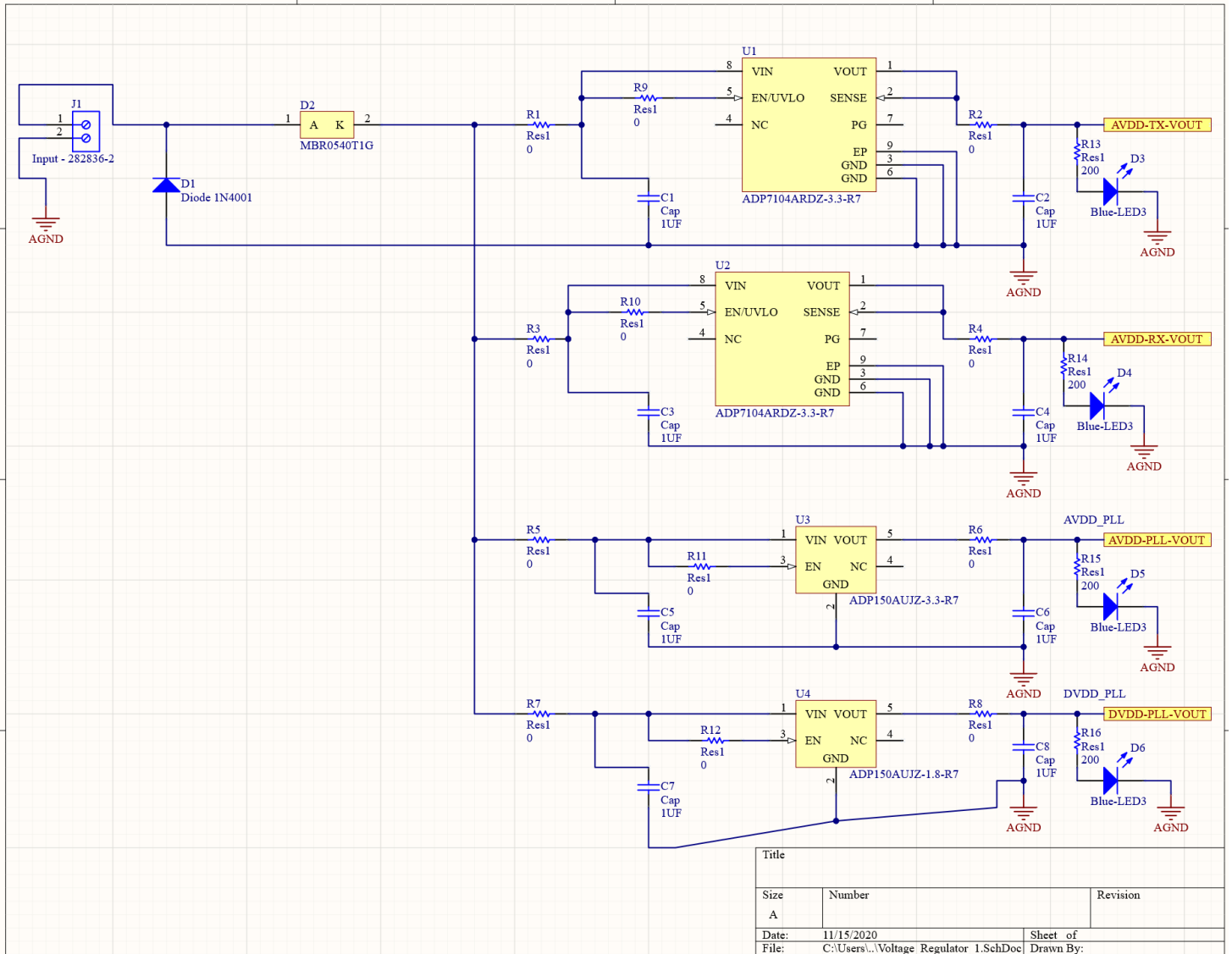


Figure 15: Power Supply Circuit Schematic