UCF | Electrical and Computer Engineering

UNIVERSITY OF CENTRAL FLORIDA

Doppler RADAR Module

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Project Narrative

The primary goal of our project is to design and build a portable doppler radar module and develop software to go with it. The module will be used to generate velocity data that can then be used for a variety of applications. For our application, we plan to feed the doppler radar data into a simple control system. The control system will be used to drive a plant that will help us clearly visualize the data the doppler radar is collecting. The secondary (or “stretch”) goals for our project will include the following: significantly reducing the overall size of the radar, expanding the module application beyond doppler, and experimenting with the frequency and power levels of the radar. This technology will be useful for further implementation in security and remote sensing applications.

When all aspects are considered, our design should be portable, medium cost, easy to deploy, highly accurate, reliable, lightweight, and lean on power consumption.

Statement of Motivation

We were motivated to pursue this project for a multitude of reasons. Firstly, designing a functioning radar system poses a technically challenging and interesting design problem for our team. We will need to investigate the transmission and reception of electromagnetic waves, design a functioning waveguide for our system, design a method of communicating this data to be seen by the operators, among other challenges. Secondly, we felt like this project would demonstrate skills we have acquired during our collegiate education. Additionally this project could be applicable and of interest to many different sectors including defense, surveying, and remote sensing.

Goals

For our project to be considered a success, we would need to first design and build a functioning mounted radar system, which will transmit electromagnetic fields of a certain wavelength and receive the reflected wave back for analysis. This data will then need to be processed and transmitted to a receiver or host device where it can be read and interpreted. For our stretch goals we would like to be able to register subsequent point cloud samples on the host device for mapping, send out different frequencies to obtain further information about the properties of the object of interest, and we would also like to be able to monitor the collected information in real-time. Information of material density or material composition (acoustic, modulated/separate, see-through object) would be an additional plus, but not a necessity.

Constraints

When tackling this project we are going to need to keep in mind key constraints that will help dictate our design process.

Regarding the manner in which we intend on mounting our system, two main constraints will be those on the weight and power supply. It is crucial to make the radar as lightweight as possible to enhance portability, and we will need to design a battery system that will keep our system operational long enough to successfully complete its task.

For our radar system itself the main constraints we will have to work around will be the frequency bands available for our use, the feasibility of the receiver design, the power of the system, the cost, and the complexity given the time constraints imposed upon us.

Marketing Analysis

The global radar market size reached $32.3 billion dollars in 2021, and is projected to reach $44.4 billion dollars by 2028. This results in a compound annual growth rate of roughly 5%. There is significant growth in the space, aviation, and defense industries. With the increase in unpredictable weather patterns, advanced weather monitoring systems use radar to gauge atmospheric conditions. Radar systems are also deployed in ocean and space surveillance, remote sensing, and missile guidance equipment. Some major players include but are not limited to Lockheed Martin, Raytheon, Northrop Grumman, and L3 Harris. With the rise of economically emerging nations deploying radar technology in passenger cars and increased demand of radar technologies for security purposes, radar companies have been increasingly profitable.

Key success factors include both the intellectual and economic resources we have at our disposal, whether our product is innovative in its application or approach, ensuring all components of our system possess satisfactory quality standards, keeping our attention to the market and our end users sharp, working as a team efficiently and effectively, and wisely using our finances. It is imperative that we keep an eye on the market's distribution channels, as select electronic products are becoming increasingly difficult to obtain in a timely manner. The cost structure in the radar market seems to be up-front heavy with long lasting continuous returns.

Similar Products:

During our initial market search we have found the following products that are relatively similar in scope or application.

1. 165683-doppler-radar
2. https://hackaday.io/project/4440-open-ground-penetrating-radar
3. https://dl.acm.org/doi/pdf/10.1145/3432221

We will be exploring more options consistently. We will add and expand on the products on the market that are similar in scope or application.

Additional Ideas/Brainstorming:

Some additional applications or uses of our system may include overhead surveillance of an area rather than "parallel" surveillance, which is our current approach. It would be an interesting challenge to see how big of an area the radar module could survey without compromising its size and power requirements.

Project Requirement Specifications

The quantitative requirements for the system can be divided into the following categories: performance, energy, manufacturability, and operational. In a full implementation of our doppler system, these requirements would include both system-specific and implementation-specific requirements. However, as we plan to use our module for a fairly simple application that places little if any additional constraint on the system, the requirements listed in this section will pertain to only the doppler module itself and the accompanying software used to process the raw data. Additional requirements can and will be added as a more concrete idea of our application is developed, or the current requirements will be modified as necessary.

Table 1 outlines the various qualities of our system and the corresponding technical characteristics that affect them. From the hardware perspective, the requirements primarily have to do with characteristics of the radar that affect its performance, and the overall size of the module. From the software perspective, the primary concern is lag time. We want to use the data generated by the radar in real-time rather than having a post-data collection analysis, so it's crucial the software can process the radar data in a timely fashion.

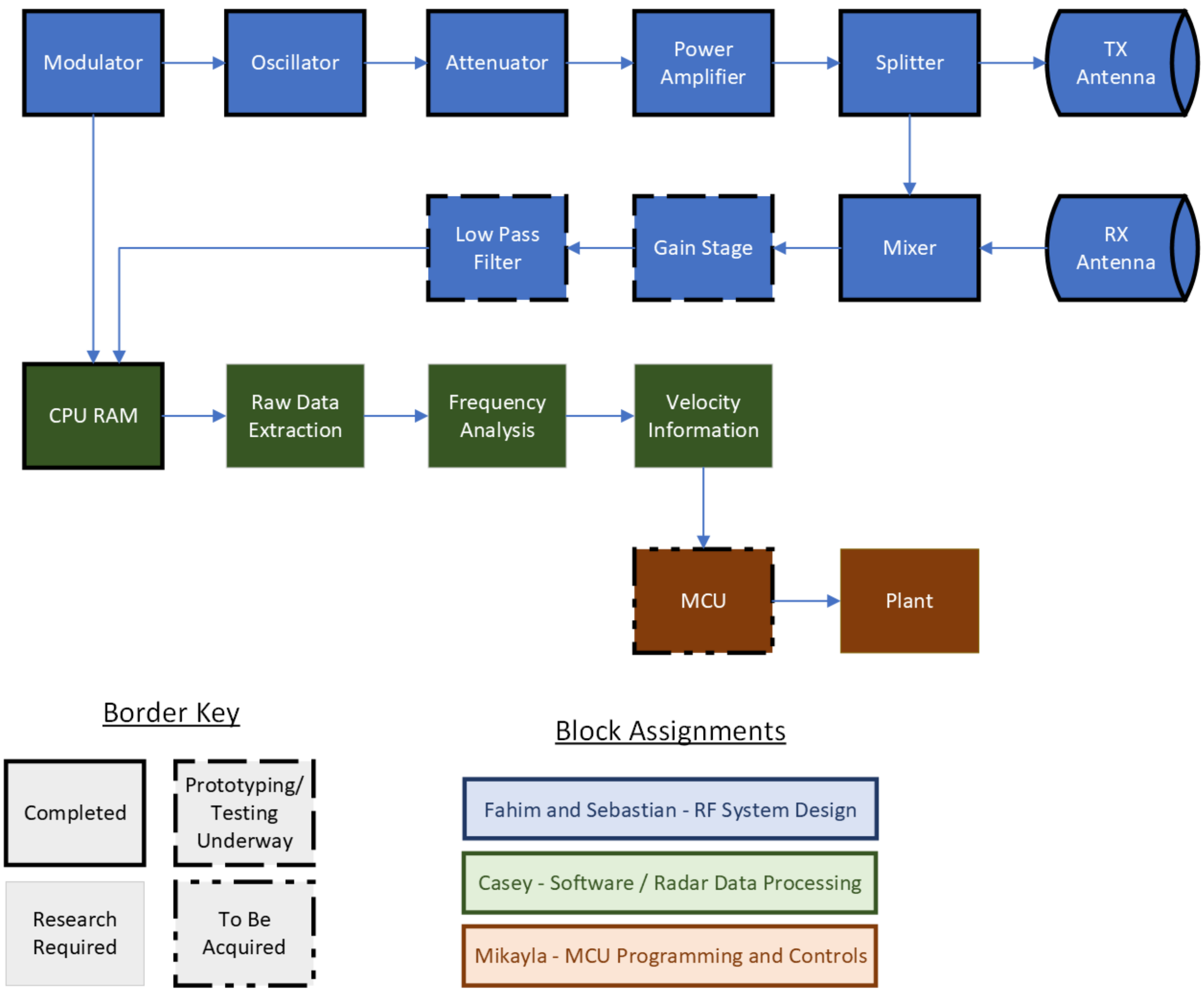
Table 1: House of Quality for Doppler RADAR Project

		Measurement error	Operating Distance Range	Runtime	Power Consumption	Cost	Size	Frequency	Output (TX) Power	Software Lag Time	Weight
		-	+	+	-	-	-	+	+	-	-
Accuracy	+	++	-		-	-	-	++	++	++	
Portability	+						++				++
Versatility	+	++	+	+	+	--	+	+	+	++	+
Ease of Use	+		+	++	+	-	++	+	+	++	++
Cost	-	+	-		+	++	-	-	-		-
Measurement error	-		-			-		++	++	+	
Operating Distance Range	-				-	-	-	-	++		
Runtime	+				+						
Power Consumption	-							-	--		
Cost	-						+	-	-		-
Size	-										
Frequency	+										
Output (TX) Power	+										
Software Lag Time	-										
Weight	-										
Engineering Specifications		+/- 10%	50 meters	>= 30 minutes	<= 50W	<= $800	<= 0.5 cubic meters	>= 2 GHz	>= 10 mW	<= 3 seconds	<= 3 kg

System Block Diagram

Figure 1 shows a block diagram of both the doppler radar system and the implementation we plan to use for Senior Design. The diagram is divided into 3 sections: the RF system, the computer software and the plant control system. Each team member has been assigned to a specific section of the project according to their technical background.

Figure 1: System Block Diagram



Financing and Budgeting

UCF professor Dr. Xun Gong has already provided our team with the majority of the components needed for our RF subsystem. Currently, our plan is to finance the remainder of the project (the IF subsystem, microcontroller, plant and any software purchases) by dividing the costs evenly between our 4 members. The cost will be relatively low due to the remainder of the project being basic electronic components and software. Table 2 shows an approximate budget for the project, including all parts we would have had to purchase prior to Dr. Gong's donation.

Table 2: Estimated BOM

Product	Cost
Mixer	6.89
RF Amp	13.46
MMIC	20.63
Connector	4.61
RF Attenuator	0.33
DAC	2.83
Op Amp	6.82
RF PCB	7.00
Antenna	34.93
Battery	32.99
Microprocessor	30.00
Total Cost	**171.96**

Milestones

Semester 1 (Senior Design 1)

Week 1	Plan regular meetings with advisor (Dr. Jones)
Week 2	Research components for design
Week 4	Plan integration of components
Week 6	Design software API to interface with hardware
Week 8	Consult experts on design and feasibility
Week 10	Simulate RADAR performance

Semester 2 (Senior Design 2)

Week 1	Finalize and order PCB design
Week 3	Solder surface mount components on PCB
Week 4	Validate hardware
Week 6	Test software
Week 8	Record findings
Week 10	Finalize paper

Decision Matrix

		Criteria		
		Weight-To-Power Ratio	Orientation	Mapping
Solutions	Stationary	Low	Horizontal (Forward - Facing)	Static Viewport / Front-To-Back Occlusion
	Ground Vehicle	Medium	Horizontal (Forward - Facing)	Front-To-Back Occlusion
	Air Vehicle	High	Vertical (Downward - Facing)	Top-To-Bottom Occlusion