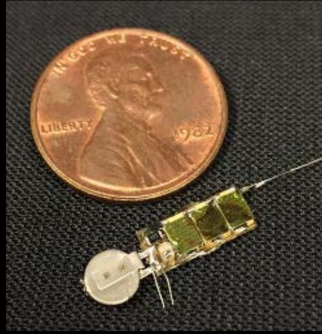
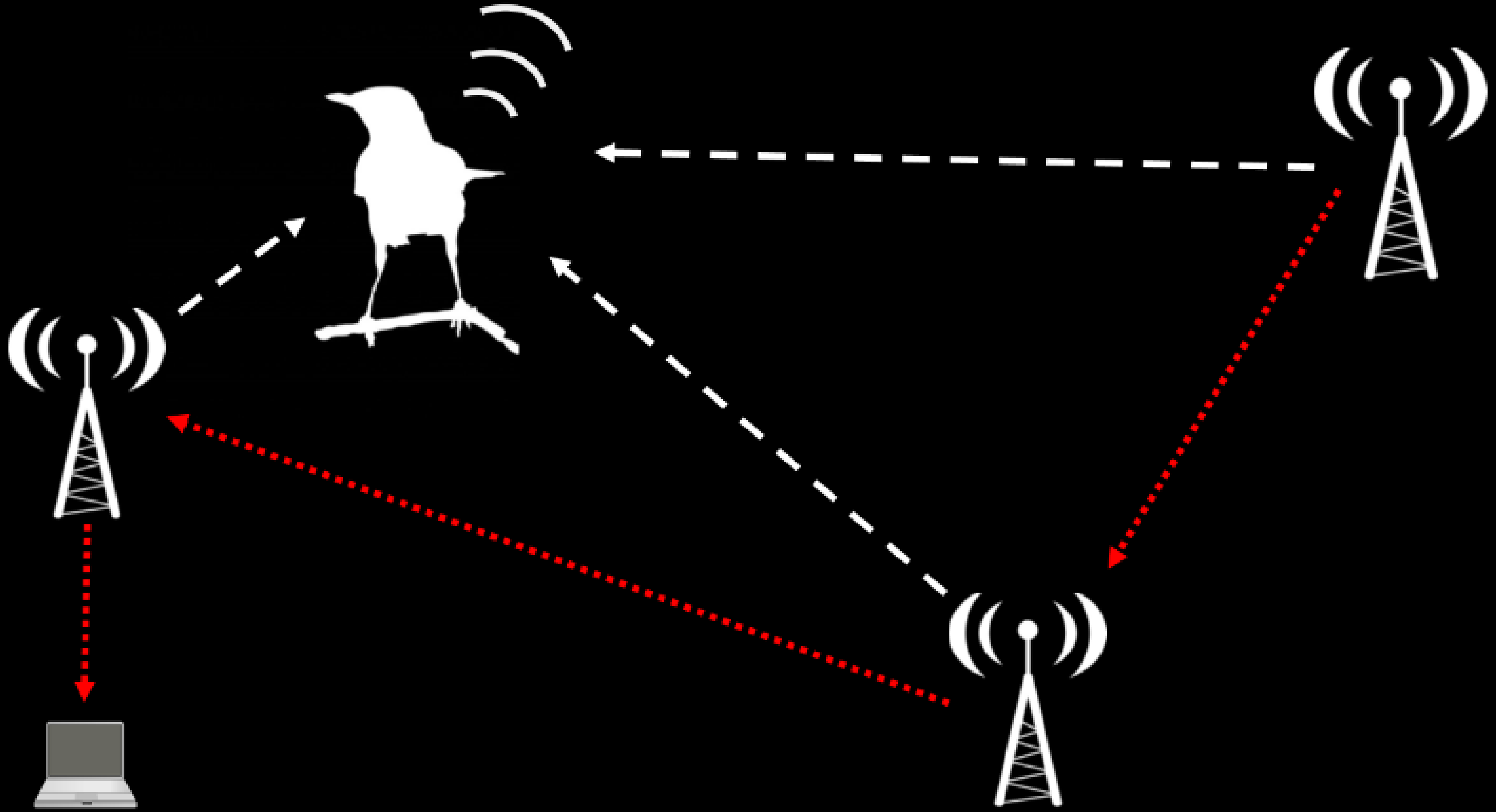
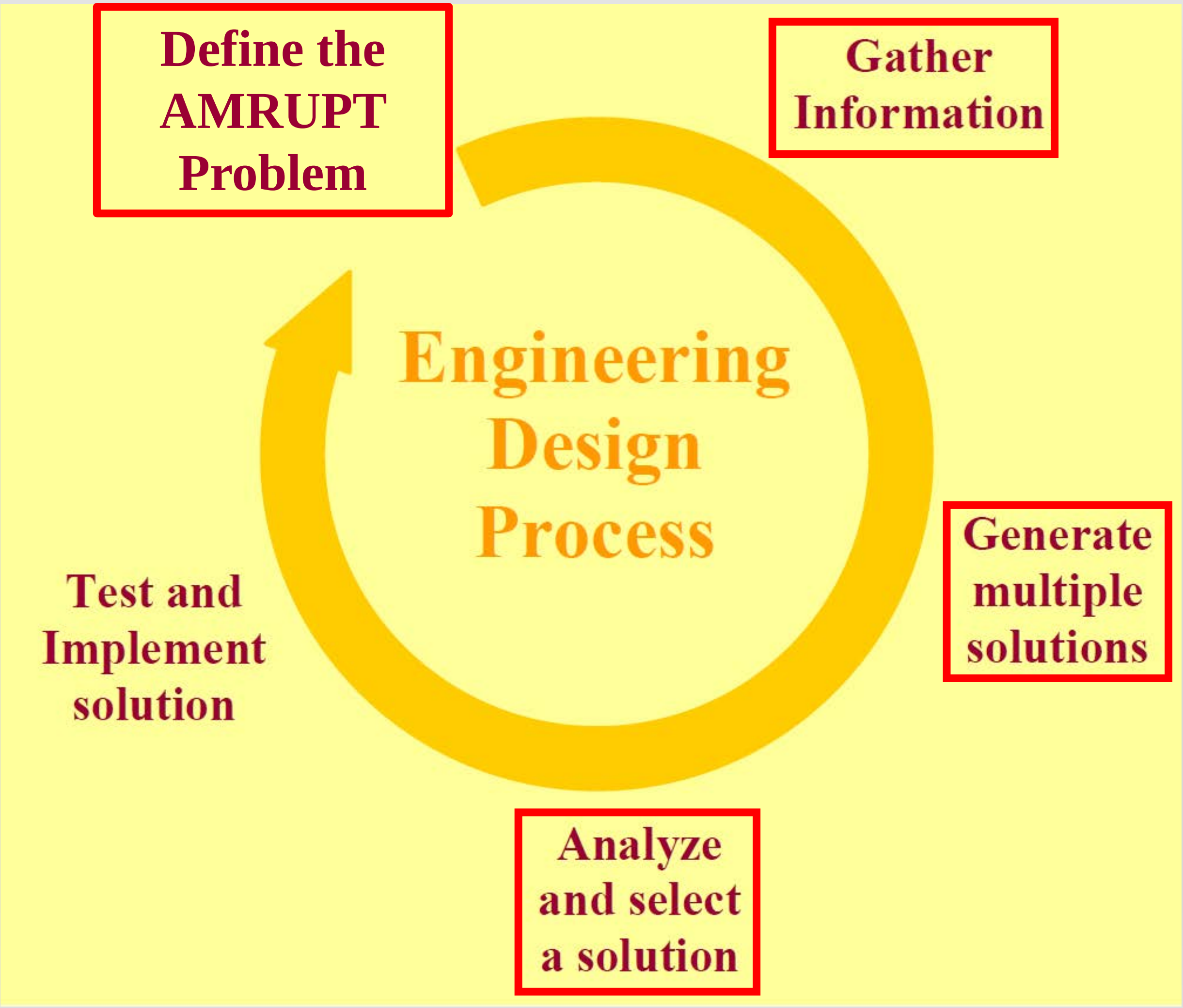
AMRUPT

(Animal Movement Research Using Phase-based Trilateration)





This week's meeting: proposal discussion



Khandani, 2005

Project Proposal

Statement of Problem: the "why?"

<u>Background information:</u>

- Relevance or importance of problem
- Background information to educate the reader about concepts relevant to the work
- Previous related work by others—literature review with credible sources
- Detailed problem description, as you now understand it

II. Statement of Problem

The localization of small animals in the field of ecology is imperative to determining the flight patterns, social interactions, or other biological attributes to most species. Many attempts have been made to determine the positioning of animals temporally and spatially in the past, but have been either inaccurate (errors over five meters) or have required constant manual human intervention. Since direction finding requires wireless telecommunication, measurements have been thwarted by multipath interference from vegetation, electromagnetic interference, or other environmental conditions. Our objective is to develop a cost effective and automated system to track animal movements within the range of five meters while taking into account expected causes of error. Our proposed system consists of a receiver architecture that is built specifically for phase interferometry direction finding to facilitate accurate measurements from radio tags on tracked individuals.

Statement of Problem: the "why?"

2 Background

In order to meet the requirements for the project, the team researched a number of topics to obtain background knowledge of radar systems and direction finding techniques. The following sections contain an overview of radar systems, focused on radar receivers, direction finding systems and techniques, and a discussion of methods to solve ambiguities that result from phase comparison direction finding.

2.1 Radar Overview

Radar systems have a myriad of uses, from radar speed detectors and air traffic control systems to missile tracking and surface mapping. Regardless of the application, all radar systems share the same general concepts and structure. A radar system is composed of several basic components: a transmitter, an antenna or antenna array, a receiver, and a signal processor (Holm and Richards, 2010). The basic functionality of a radar system is shown in Figure 5.

Objectives: the "what?"

- Objectives list
  - Ignore advice to limit to 4 points. We need to fully define the “what”

(1) The receiver system is low-power and can track up to 50 lightweight and low-power radio tags

(2) System architecture is resilient in cluttered environment (unsusceptible to multipath interference, electromagnetic interference, and other environmental conditions)

(3) System is able to achieve two dimensional high spatial accuracy (error for triangulation results is limited within 5 meters) with a 100-300m distance between receivers

(4) System is cost-efficient (almost all components are commercially off-the-shelf)

5) **Forward compatibility**: Must be compatible with and adaptable to a multi-frequency-phase-integer-disambiguation approach for future versions

Objectives: the "what?"

- **Don't detail the "how"** until you get to the technical approach section

The first objective is to successfully track the locations of 50 individuals in the testing environment. We need to design the tags as lightweight as possible since the individuals are small in size and heavy tags may affect the individuals' biological activities. To allow for the least possible human intervention during the tracking process, both the receivers and tags need to operate with minimal power consumption to increase automatic tracking period. In addition, both the transceivers (ground nodes) and tags (mobile nodes) follow a communication protocol in which the mobile nodes will go to sleep when they are not communicating with the ground nodes to reduce power consumption. The communication protocol specifies that the mobile nodes wake up every 5 minutes to prepare for data transmission to the ground nodes. The mobile node will receive a 5-second countdown signal once it wakes up. As soon as the mobile node is verified to be within the receiver's range and has good link, it will be synchronized to global time before it is given a scheduled transmission time by the receiver or sent back to sleep again. If the mobile node is not within range of any receiver, it will go to sleep and wake up every 5 minutes to check whether it's within range again. The complexity of the ground to node communication protocol will be governed by how accurate our receivers are when taking angle of arrival measurements. If angle of arrivals from a couple of basestations intersect to a triangulation area of no more than 5 meter error (discussed further) over the specified tracking area, then tags will not have to be linked to different receivers depending on location. The communication protocol will also be used for a multi-frequency system, which is a possibility in the future of this project.

Furthermore, the system must be able to obtain accurate results in a cluttered environment. We agreed that a real environment would have substantial multiple interference as there will be trees and rocks that can reflect a wireless signal. The multipath interference could result a false transmit signal which would give us wrong information about the location of the tags. We have proposed a low frequency phase interferometry system to mitigate multipath interference. Additionally, our system will have the option of being further designed to overcome this interference by frequency hopping with to obtain minimum variation results.

Technical approach: the "how?"

1. What are the proposed solutions to achieve the previously outlined objectives for this project?
   a) Refer (explicitly) to workable solutions from others' **previous work**
   b) Explain design **tradeoffs, constraints**
2. How will you analyze the performance of your solution? How will that analysis inform design choices?
   a) Explicitly detail **which tests** you will perform to inform which decisions
   b) Explain the what the test **result values would mean**? I.e. How will these values **influence the design process**??
      a) Example: From "study A," which used a sampling rate of B to achieve spatial resolution C we extrapolated, using equation D, that we would need a sampling rate of E to achieve our specified resolution of C'. Test F will evaluate whether we are within our target resolution of C'. If test F reveals that our resultion is <C', we will increase sampling rate using equation G, developed by "Study H."

Technical approach: the "how?"

- Be specific!

IV. i. Receiver Architecture

We first propose a receiver architecture that consists of an embedded device to simplify wireless communication and improve the cost effectiveness of this project.

The ideal embedded device would include the following:

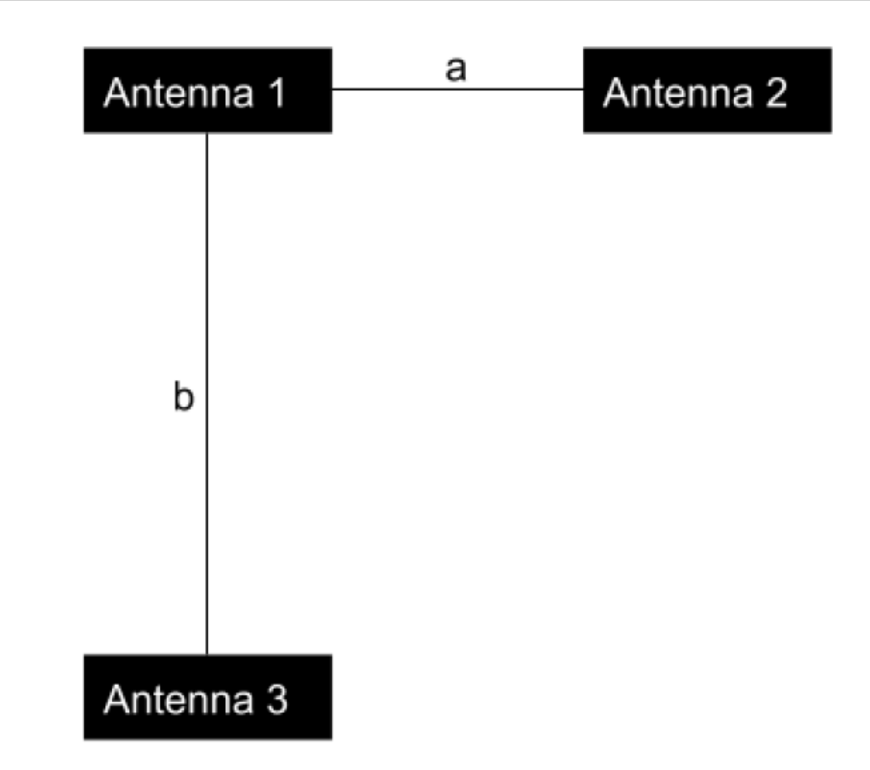
1. A sub 1-GHz device for UHF frequencies transmitted from radio tags. We choose a lower frequency band (relative to most RF applications) to mitigate multipath interference and better determine the phase difference of signals.
2. A very high sample frequency during the analog to digital conversion of RF signals. This is essential for determining accurate phase differences from radio waves moving at the speed of light.
3. Ample UART/I2C/SPI/GPIO connections for data logging and transfer
4. Contains every component necessary for receiving an RF signal from an external antenna - ADC, local oscillator, etc.
5. Extremely high RF sensitivity and blocking performance
6. Programmable and highly used by the public - helpful for finding more tutorials and readily available information on the device
7. Low power and low cost

Technical approach specifics

- UHF = 300 MHz – 1 GHz → **system was to operate on 150 MHz (Why?)**
- "With this system, only offsets from the antenna geometry or the wire lengths/connectors from each antenna to the switch could contribute to phase difference errors between each antenna, eliminating the need for Equalization with LFMs." **How will we know if this actually poses a problem?**
- "This setup would require the use of multiple GPIO ports and multiple chained switches to accomplish our goal of having 3 antennas." **Figure showing proposed architecture. Is this really the best way to do this? No 3 output relays suitable? What other considerations are important for the switch [Isolation and Insertion loss]? How will these effects be evaluated?!**
- "SPI has the fastest data transfer rate. UART is easiest to set up. **Without knowing the maximum data transfer rate**, we choose to use UART for test purposes." **We CAN know the maximum data transfer rate required, through simulation and modeling.**
- "We will run a program on Raspberry-pi to log those [the AOA] data." **If this is part of the proposal, be explicit about how this will work.**

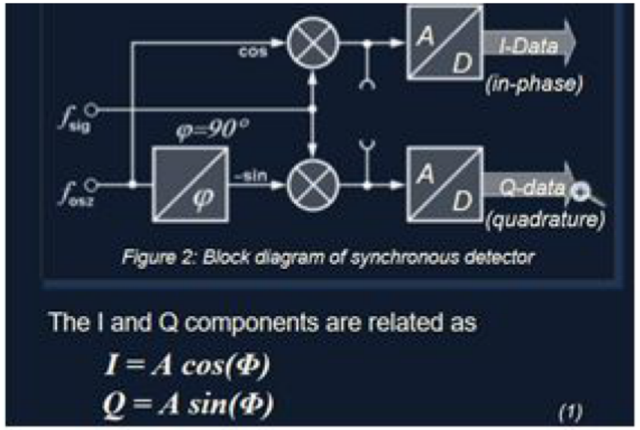
Technical approach specifics: Antenna array

- "The simplest way to remove ambiguity is to place the interferometer's two antennas less than λ/2 apart; however, this cannot be used for *our* application."
- "Comparing the phase difference from antennas 1 and 2 to the phase difference of antennas 2 and 3" **What's wrong? Antenna array as designed, is not equally sensitive in all directions: 3-to-1 phase difference calculations could ameliorate this.**



Technical approach specifics: AOA estimation

<u>This is not the setup being proposed!</u>



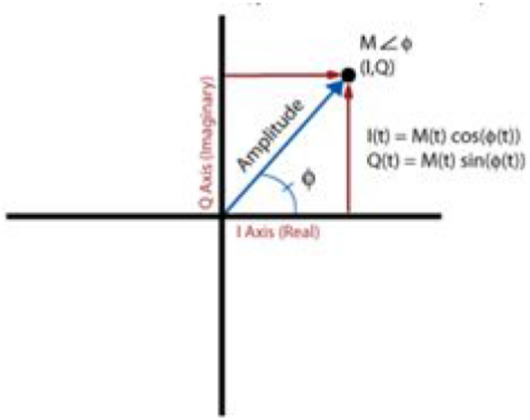


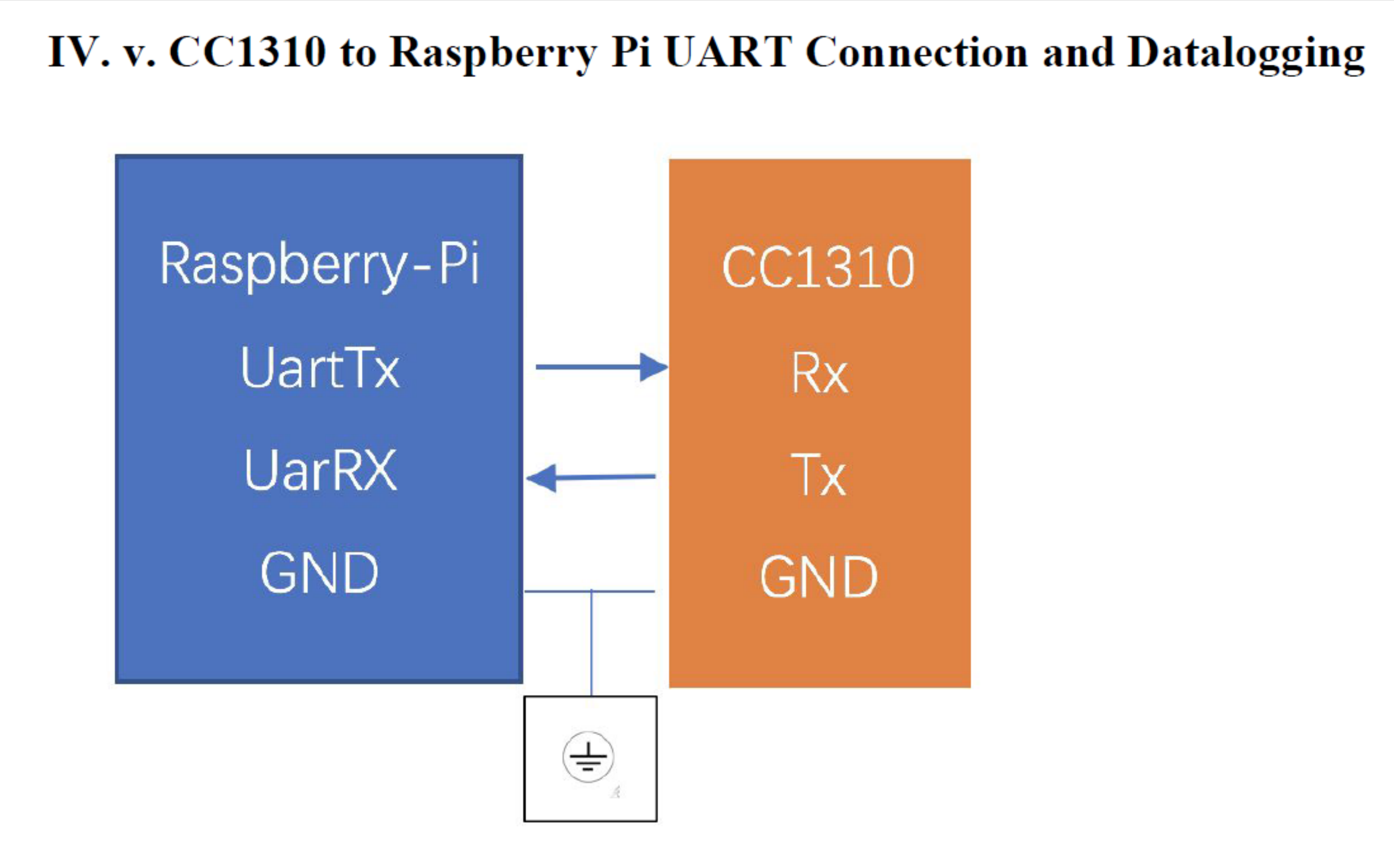
Table 1. Format of IQ Samples Stored in RAM

Byte	Bit Definition							
0	I_7	I_6	I_5	I_4	I_3	I_2	I_1	I_0
1	Q_3	Q_2	Q_1	Q_0	I_{11}	I_{10}	I_9	I_8
2	Q_{11}	Q_{10}	Q_9	Q_8	Q_7	Q_6	Q_5	Q_4

Figure 3: A radio frequency signal can be decomposed into a real and imaginary value top-right. The in phase and quadrature information can be obtained from the top-left setup. I/Q Samples are stored in RAM using 3 byte data packages (bottom).

Technical approach specifics

<u>This is not the correct pinout for the CC1310 (Rx and Tx pins are the RF pins)</u>



Management plan

- Explain your Gantt chart in the text of your document!!
- Be specific!

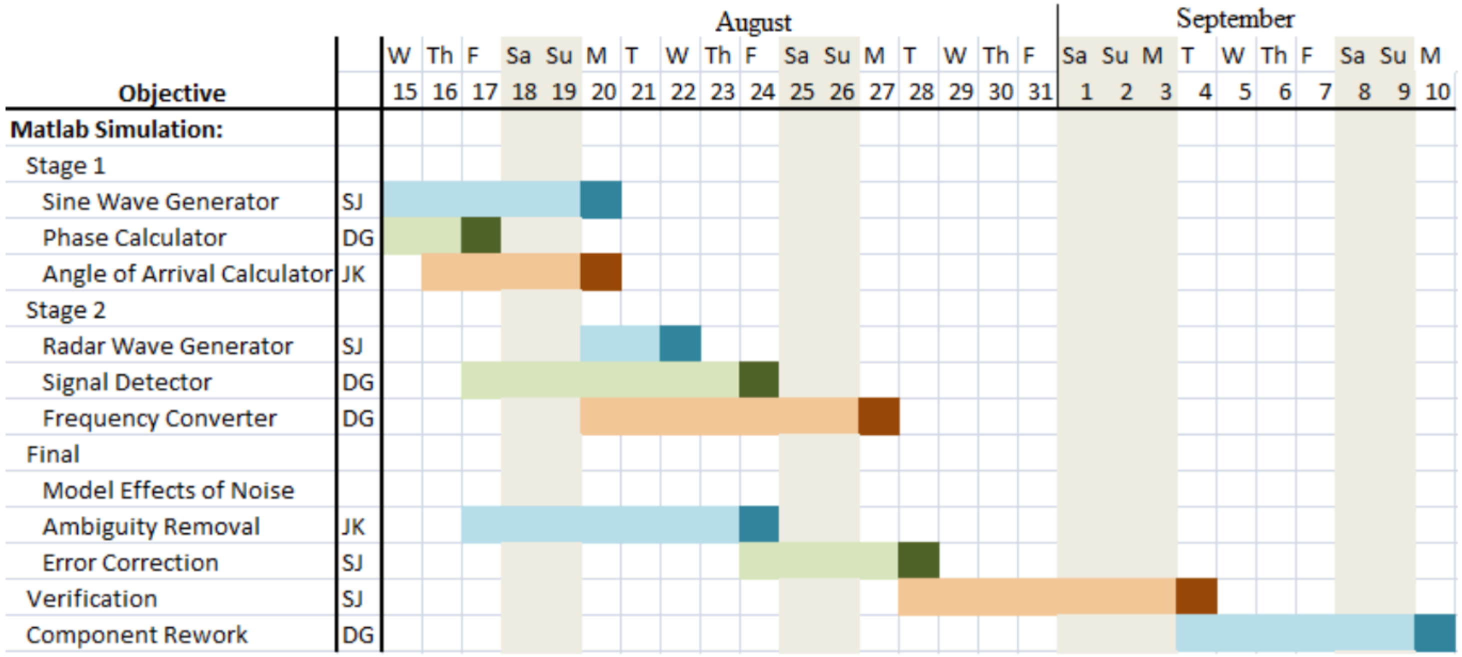
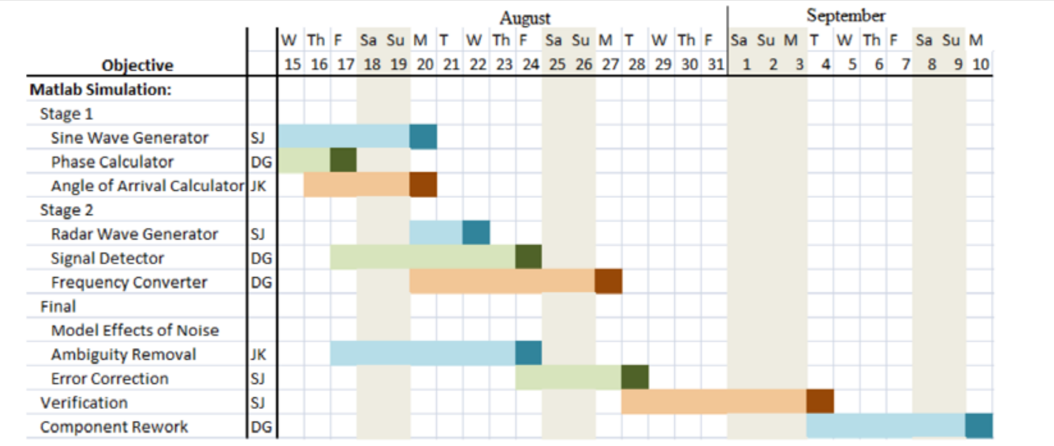


Figure 21: Gantt chart showing the schedule for the MATLAB model. Work began on August 15th, 2012 and continued to September 10th, 2012. Each component was developed by a different individual whose initials are shown in the second column. The components are grouped into iterations representing significant improvement in the system.

Management plan

- Milestones? Phases?
- Explain phases of project: How are you managing the work? How are you approaching task allocation?
  - Example 1: What does “Antennas” mean? What will be accomplished?
  - Example 1: How does “Matlab Simulation” fit in? Why is it there?
  - Example 2: “Testing” what? When? What does it accomplish?

Task Name	Start Date	End Date	Duration	% Complete	Status	Assigned To
Phase 1(AOA)	**18-01-24**	**18-05-25**	**88d**	**8%**	**In Progress**	
Project Proposal	18-01-24	18-02-21	21d	100%	Completed	Russell Silva, Mei Yang, Justin Cray, Peidong Qi
Antennas	18-02-21	18-03-21	21d	0%	In Progress	Justin Cray
RF Switch	18-02-21	18-03-21	21d	0%	In Progress	Justin Cray
CC1310 I/Q Extraction	18-02-21	18-03-21	21d	0%	In Progress	Russell Silva
CC1310 to Raspberry Pi UART Connection and Datalogging	18-02-21	18-03-21	21d	0%	In Progress	peidong qi
Phase Disambiguation and Angle of Arrival Calculation	18-03-21	18-05-15	40d	0%	Not Started	Russell Silva, Mei Yang, Justin Cray
RF Wave Reconstruction and Matlab Simulation	18-02-21	18-04-18	41d	0%	In Progress	Mei Yang
Angel of Arrival Measurement	18-02-21	18-05-15	60d		In Progress	
Testing	18-04-24	18-05-25	24d		Not Started	
Separate Demodulator/ADC (Plan B Solution)						Russell Silva, Mei Yang, Justin Cray, Peidong Qi



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Deliverables??

Deliverables

The culmination of the proposal negotiation with your sponsor will be a completed "Deliverables Agreement." In this section, provide a *detailed* description of what you are providing and when you will provide it. Be as specific as possible. Possible items include

Detailed design drawings (specify Computer Aided Design format)
Physical prototype
Scale model
Engineering analysis (Finite Element Analysis, MATLAB, etc.)
Economic analysis (return on investment calculations)
Detailed description of test procedures
Data from experiments
Computer program code, flowchart, documentation
Circuit diagrams
User-friendly instructions including training for personnel

Formatting and citations

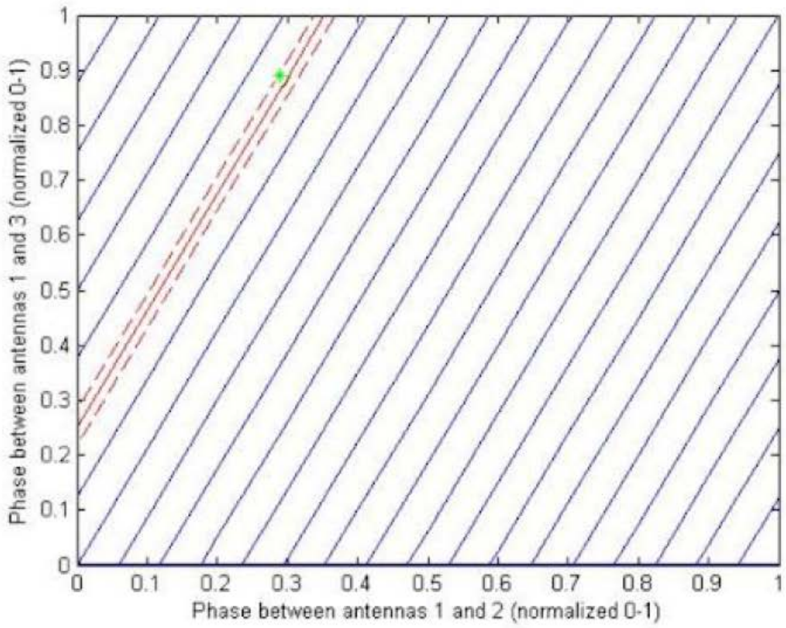
<u>Issues/Points of clarification:</u>

- Label ALL figures
- Discuss any figure or table in the proposal. Don’t include anything you’re not going to discuss.
- Don’t use others’ figures or equations without attribution!! **This is plagiarism!**

Formatting and citations

determining the number of full phases for a phase offset.

$$\Delta\phi'_{13} = \frac{s_{13}}{s_{12}}\Delta\phi'_{12} + \frac{s_{13}}{s_{12}}i_{12} - i_{13}.$$



We do not believe that the 90 degree offset from quadrant disambiguation will affect the

Formatting and citations

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- Don’t use others’ figures or equations without attribution!! **This is plagiarism!**
- Check carefully for typos, unclear language: these can lead to total misinterpretation!
- Define acronyms and terms:
  - Example: “…eliminating the need for Equalization with LFMs” **Explain what this means**