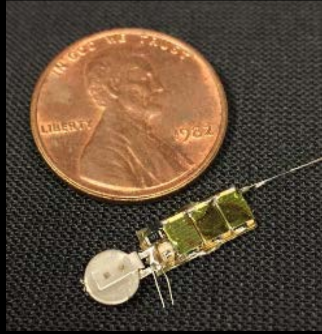
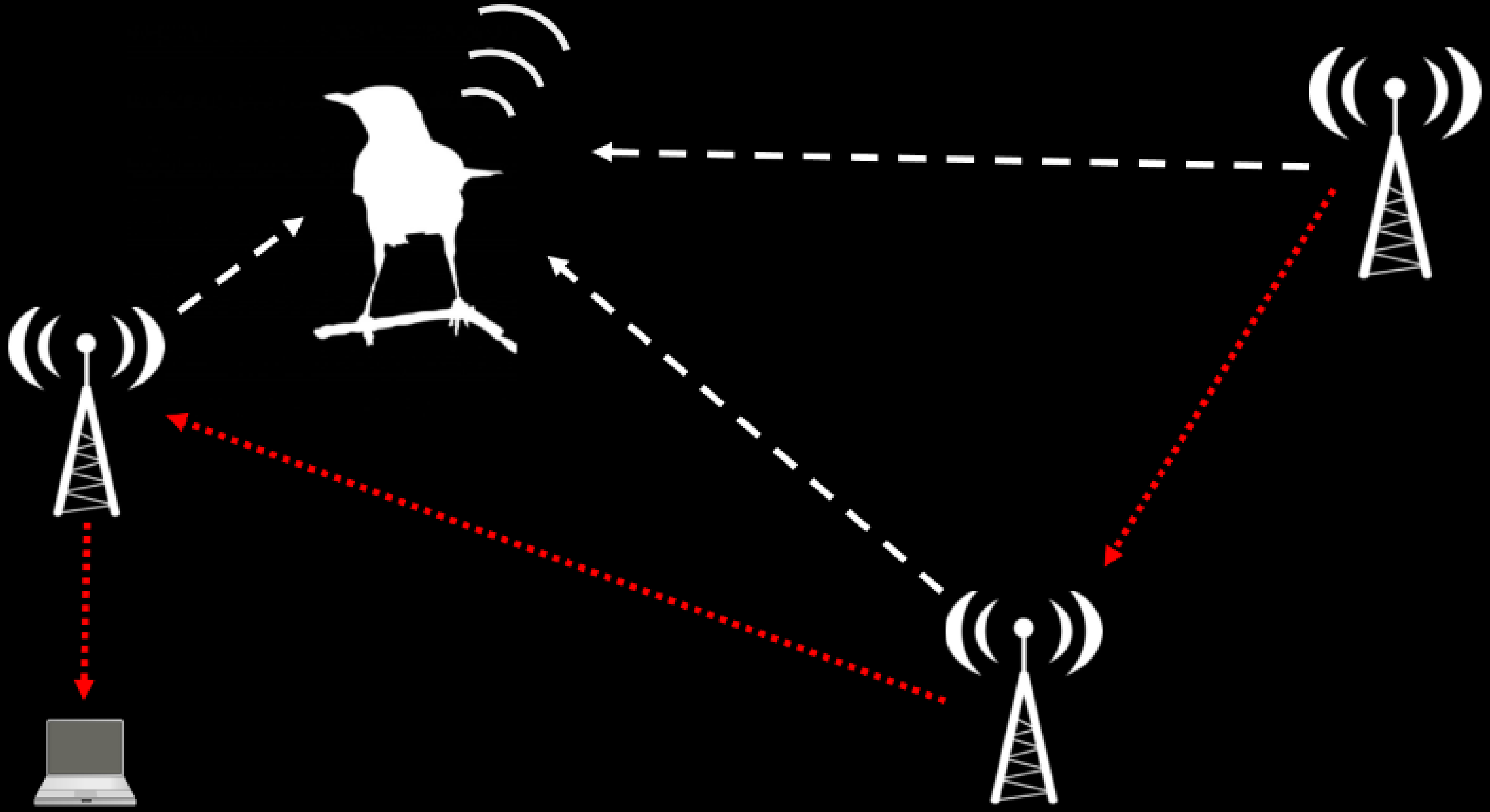
AMRUPT

(Animal Movement Research Using Phase-based Trilateration)





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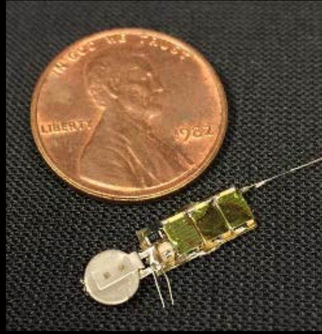
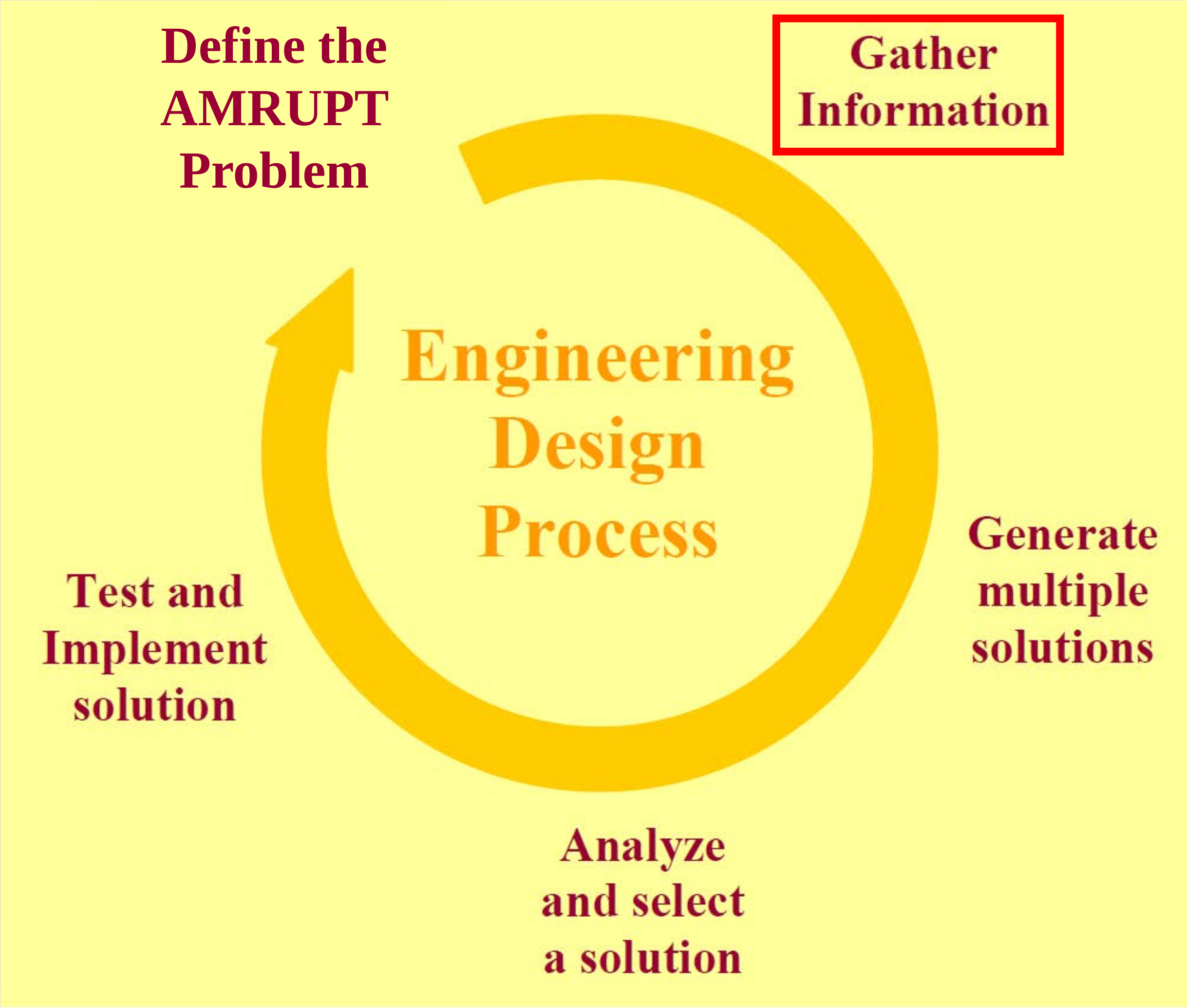


- By the third week of the semester you will submit a project proposal (details provided in syllabus) covering the current phase of the AMRUPT project.

- Failure to submit 3 or more weekly updates will result in the student being dismissed from the project. Updates may not be submitted late.

Proposal: literature review section



Khandani, 2005

Project Proposal

Literature Review: what's the purpose?

1.1 Prior arts and related works

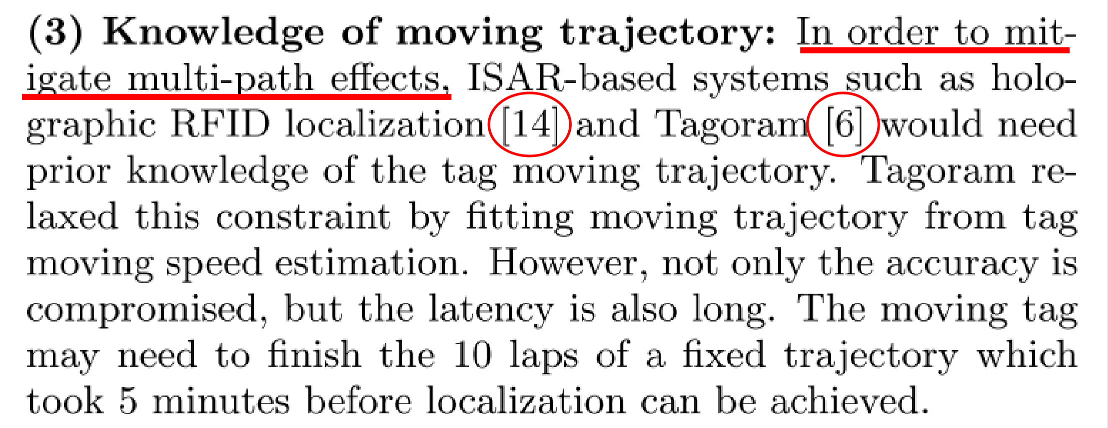
Although passive tags can provide a distinguishable signal from ambient radio frequency (RF) reflections, accurate localization is still a very challenging task due to the rich scattering indoor environment. Among RFID localization methods, received signal strength (RSS) [1, 4, 31, 30] suffers from poor accuracy and reliability due to multi-path interference since RSS is not a sensitive function of distance. Time of flight (TOF) is not suitable for short range due to the synchronization difficulty, signal sampling complexity in capturing an ultra-wideband (UWB) wave packet in passive devices [5], and measurement of nano-second round-trip delay [13]. Carrier phase-based methods are preferred for their ultra-high sensitivity as a function of distance [3, 8].

In recent years, several phase-based systems had been proposed, such as holographic tag localization [14], Tagoram [6], RF-compass [10], PinIt [15], Backpos [12] and RF-IDraw [7]. However, these systems came with a variety of constraints

Cons of approaches of references 1, 4, 5, 13, 30, 31

Pros of approaches of references 3, 8

Literature Review: how's it organized?


(3) Knowledge of moving trajectory: In order to mitigate multi-path effects, ISAR-based systems such as holographic RFID localization [14] and Tagoram [6] would need prior knowledge of the tag moving trajectory. Tagoram relaxed this constraint by fitting moving trajectory from tag moving speed estimation. However, not only the accuracy is compromised, but the latency is also long. The moving tag may need to finish the 10 laps of a fixed trajectory which took 5 minutes before localization can be achieved.

What to focus on?? Topics relevant to goals!

Constraints to be overcome and approaches that hold promise

The studies provide the examples of identified constraints or promising approaches

Literature Review: how's it organized?

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From the proposal

Řeřucha et al. [12] developed an architecture to use location tracking for ecological field studies. This architecture presents a network of automated trackers and software to facilitate tracker operation.

Smith, Balakrishnan et al. [15] developed a chip which uses a combination of RF and ultrasound technologies to provide location information to attached host devices. When this pulse arrives, the listener obtains a distance estimate for the corresponding beacon by taking advantage of the difference in propagation speeds between RF (speed of light) and ultrasound (speed of sound).

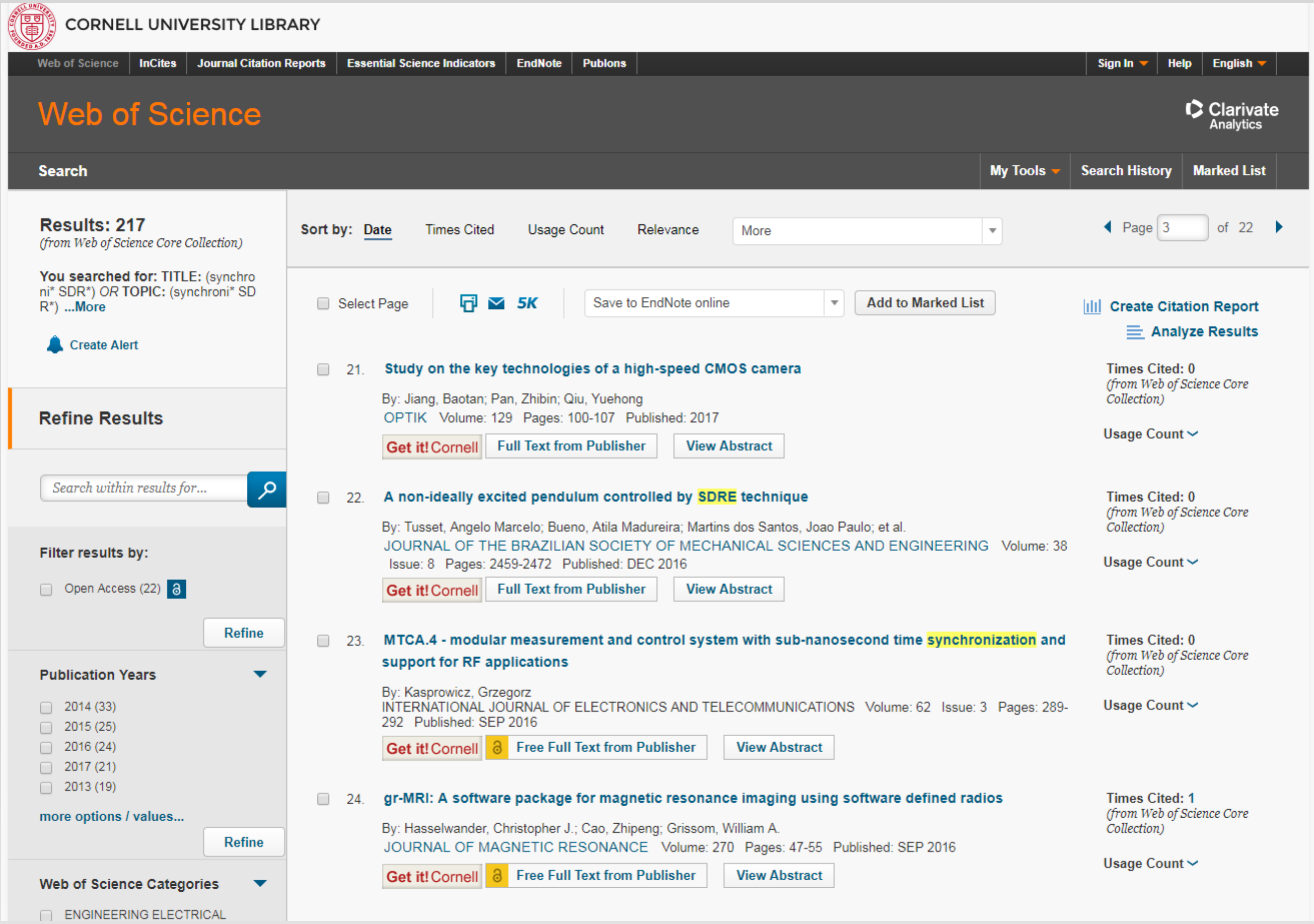
Literature Review: where to find resources?

Other papers

(3) Knowledge of moving trajectory: In order to mitigate multi-path effects, ISAR-based systems such as holographic RFID localization [14] and Tagoram [6] would need prior knowledge of the tag moving trajectory. Tagoram relaxed this constraint by fitting moving trajectory from tag moving speed estimation. However, not only the accuracy is compromised, but the latency is also long. The moving tag may need to finish the 10 laps of a fixed trajectory which took 5 minutes before localization can be achieved.

Don’t depend on GitHub!

Web of Science



Design objectives: forward-compatibility

In order to accomplish at least a 5 meter accuracy, a line of more than five meters cannot be drawn within the triangulated area of error. This area of error will be determined by $\alpha 1$, $\alpha 2$, and $\alpha 3$ (Figure 1) which resemble the angle of arrival error from receiver 1, 2, and 3 respectively. $\alpha 1$, $\alpha 2$, and $\alpha 3$ will be determined by phase difference errors from a transmitting RF signal to multiple antennas. Sources of AOA error are further discussed in the technical section of this proposal, and simulations have been planned to find algorithms that can make additional steps in minimizing this error.

Fourth, we have devised a system that is composed of cost-effective, off-the-shelf components. This is done to make this setup more reproducible in future works and more accessible to ecological hobbyists/researchers.

What are the basic requirements for being forward compatible??

IV. Technical Approach

The entirety of the proposed direction finding system consists of radio transmitters and receivers. This section will focus primarily on receiver design as the lightweight radio

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Technical Approach

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, technical analysis, simulations,** or **indicate how you will evaluate solutions**
   b) Explain design **tradeoffs, constraints,** and **back up your claims with citations**
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 what the test **result values would mean**? I.e. How will these values **influence the design process**??

Technical Approach:
Receiver architecture

Synchronization technique	Pros	Cons	Error	Refs
Time-modulated array	• Single radio (no synchronization needed) • No complicated positioning algorithm • Low cost	• Poor accuracy (?) • More susceptible to noise	10%, 0.8%	Baik et al (2017), Ma et al (2016)?
Mixer-demodulator-ADC, driven by common LO	• High accuracy • Low susceptibility to noise	• Multiple mixers/demodulators to be coupled with LO • May be expensive / complex	0.415 degrees	Guerin et al (2012)
Beacon synchronized	• Cheap • Can use SDRs	• Low accuracy • Multiple radios • Beacon position and radiation pattern must be controlled	15%	Chen et al (2012)
Internal signal synchronization	• Cheap • Can use SDRs	• Accuracy low (?)	1 sampling period	Bartolucci et al (2016)

Technical Approach:
Receiver architecture

Will the CC1310 be sufficient for any of these approaches?

What about SDRs?

Technical Approach:
Ambiguity

1. Phase disambiguation section of proposal excellent example of technical analysis based on previous work
   a) Are distance and quadrant ambiguity actually concerns?
   b) Use the same kind of analysis (in depth reading about existing systems) to justify other important design choices:
      i. Antenna geometry
      ii. RF switching methodology (pros, cons, alternatives)
      iii. Undersampling and effects on DF
      iv. Beacon-based versus equalization-based channel synchronization

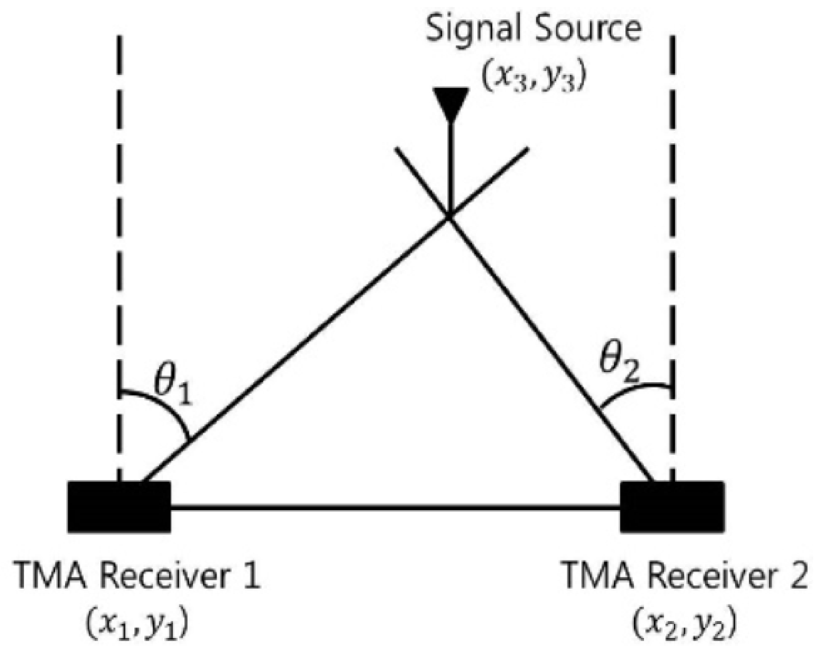


Fig. 3. Diagram of a local positioning system based on the AoA.

Technical Approach:
Antenna geometry

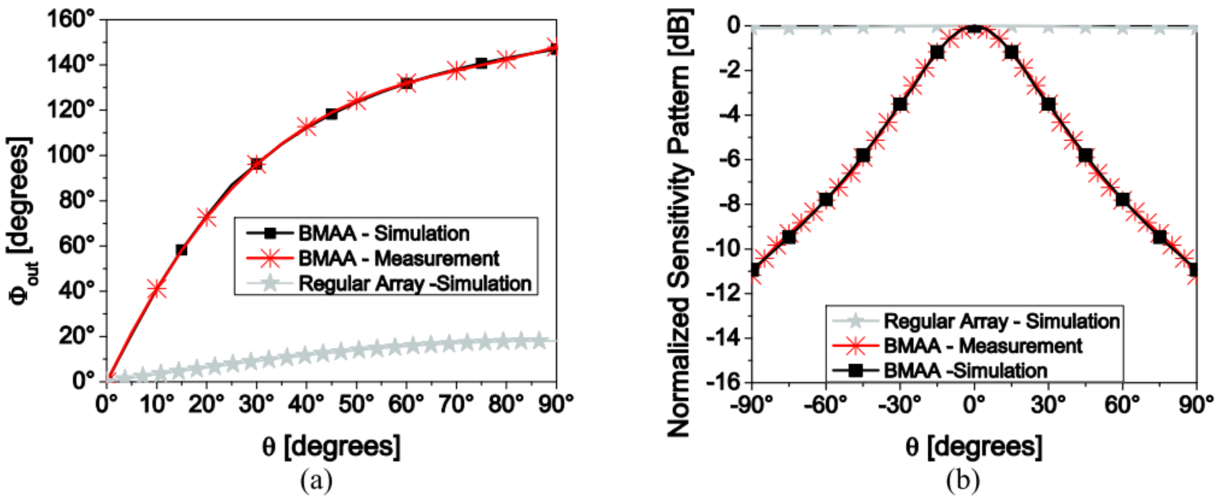
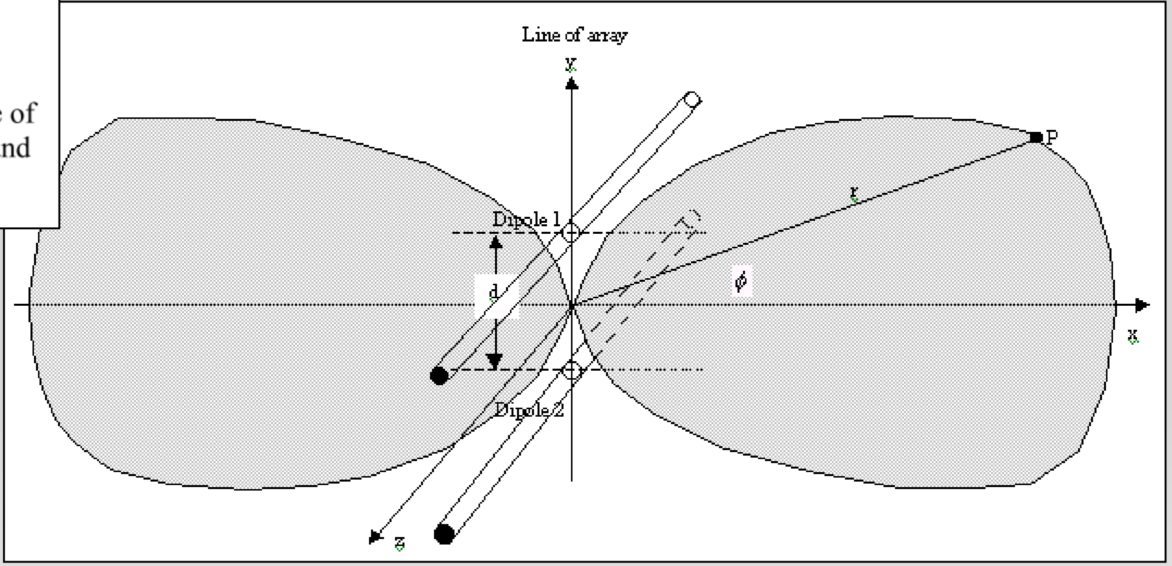
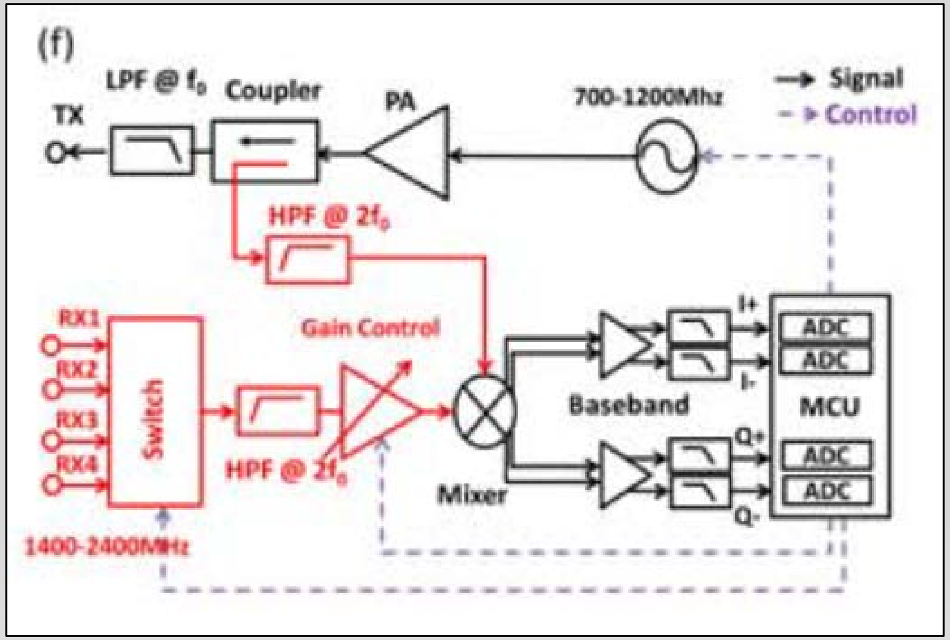


Fig. 9. (a) Measured and simulated phase responses of the biomimetic array shown in Fig. 7 and those of a regular array with identical elements and spacing (but without the BMAA circuitry). (b) Measured and simulated sensitivity patterns of the two arrays.



Technical Approach:
RF switch



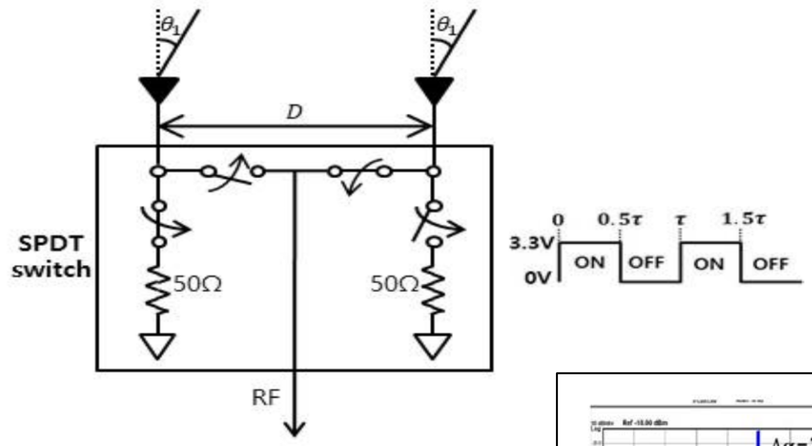
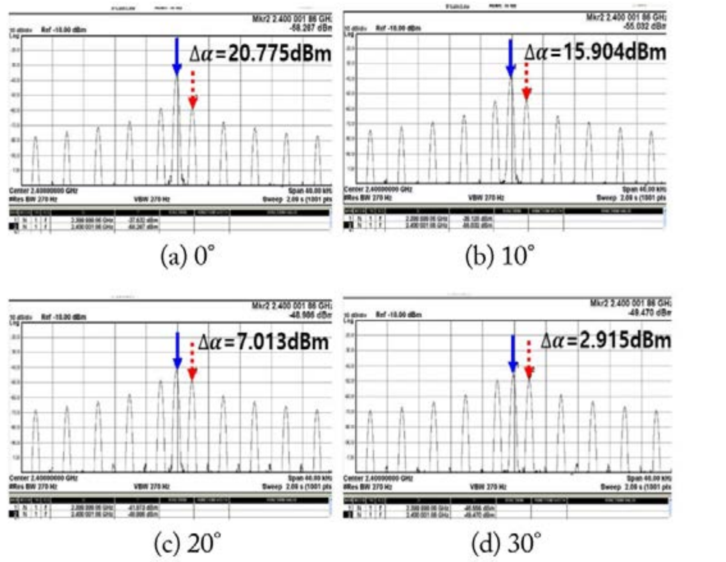


Fig. 1. TMA receiver for direction finding.



(a) 0°
(b) 10°
(c) 20°
(d) 30°

Fig. 2. Power spectrum of four different directions ($\Delta\alpha = \alpha_0 - \alpha_1$).

Technical Approach:
Raspberry Pi

What technical analysis led to the choice to use UART?!

E.g. If studies 1-7 (or simulation X, Y) indicate required sampling rate **> 500 ksps**

	~~UART~~	SPI	~~I2C~~
Speed	100 ksps	1 Msps	55 ksps
# I/O ports	2	5	2

Technical Approach:
Channel equalization

None versus Beacon versus LFM equalization

Support your assertions with data from other studies!

Beacon-synchronized

Run	1	2	3	4	5	6	7	8	9	10
Angle (degree)	0	0	5	10	15	20	25	30	35	40
Target to R distance (m)	16.15	16.15	16.15	16.15	16.15	16.15	16.15	16.15	16.15	16.15
Target to G distance (m)	14.02	14.02	12.95	11.88	10.83	9.81	8.84	7.94	7.16	6.54
Localization Error (m)	**2.03**	**0.82**	**0.17**	**2.43**	**2.00**	**1.77**	**1.23**	**4.52**	**3.39**	**1.63**
R Phase Error (%)	8.36	3.24	0.03	10.58	0.62	4.83	6.13	18.54	12.57	0.10
G Phase Error (%)	5.52	0.63	0.49	6.98	13.18	10.14	8.65	5.32	4.22	1.65
R measured phase variance (degree)	2.37	4.01	4.02	2.65	5.43	4.64	25.41	7.40	5.28	17.91
G measured phase variance (degree)	2.66	2.38	3.17	2.66	5.58	3.09	2.56	2.26	2.29	2.22

TABLE I: Localization performance. The first row is the target's angle from R's perspective. Localization error is the distance

vs.

Internally-synchronized

TABLE I. MEAN μ_θ AND STANDARD DEVIATION σ_θ OF THE SYNCHRONISATION OFFSET AND TDE ERROR FOR THE LTE APPROACH.

(a)

Sampling frequency	Signal source	Sync. pulse	Sync. offset μ_θ (ns)	Sync. offset σ_θ (ns)	TDE error μ_τ (ns)	TDE error σ_τ (ns)
5 MHz	LTE	AFG	1.45	82.56	0.40	1.34
		1PPS	-0.55	80.10	0.44	1.34
10 MHz	LTE	AFG	2.12	40.19	0.47	1.32
		1PPS	0.91	40.69	0.42	1.36
20 MHz	LTE	AFG	0.60	19.73	0.49	1.46
		1PPS	0.81	20.62	0.13	1.49

Technical Approach:
RF wave reconstruction and Under-sampling

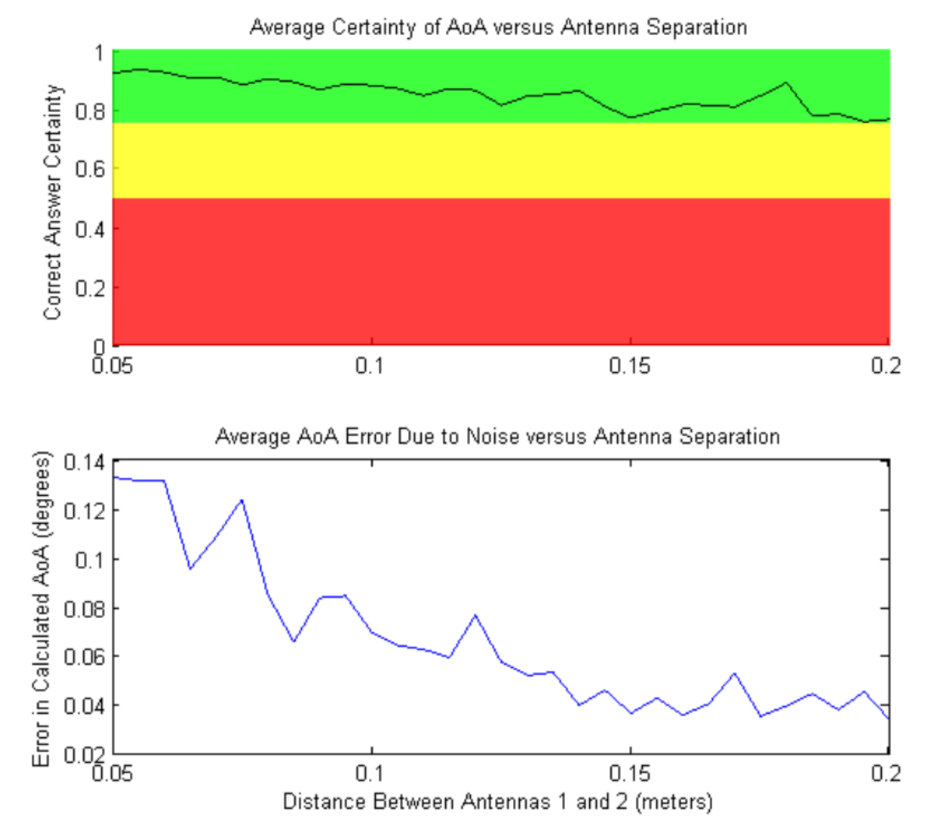
Is 200 ksps (CC1310) adequate?

How will we know (and at what stage in the design)?

Other systems use sampling rates of > 20 Msps. Why? How?

What happens with undersampling as our Tx RF signal becomes less stable?

Technical Approach:
Standardized tests

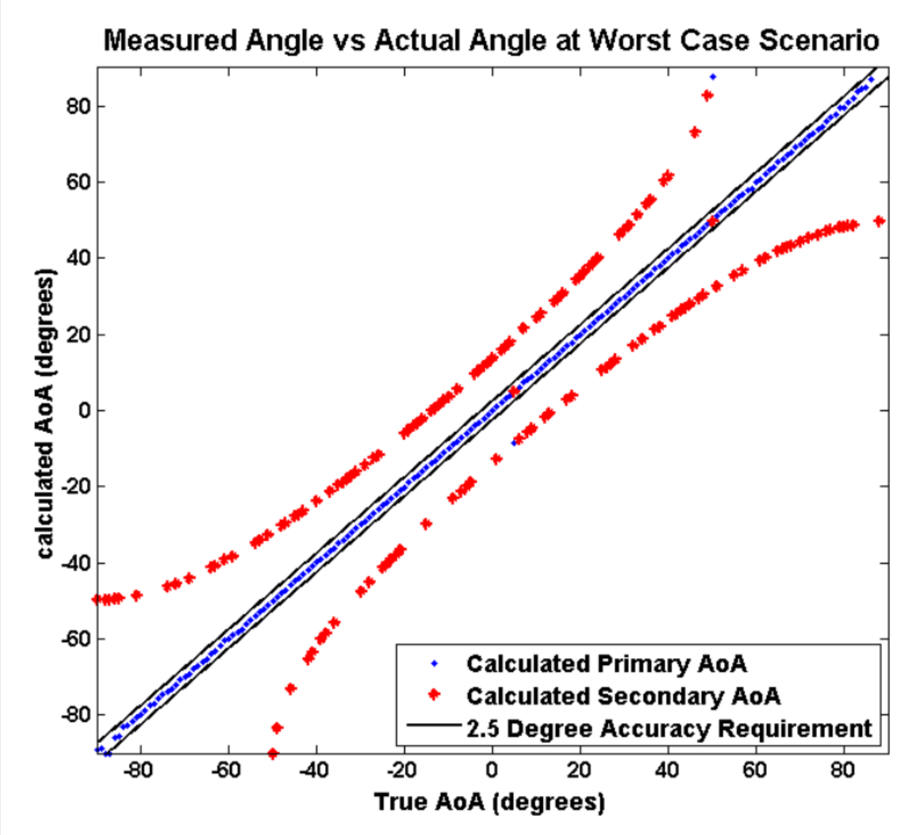


Average **certainty** that the best AOA estimate is the true AOA

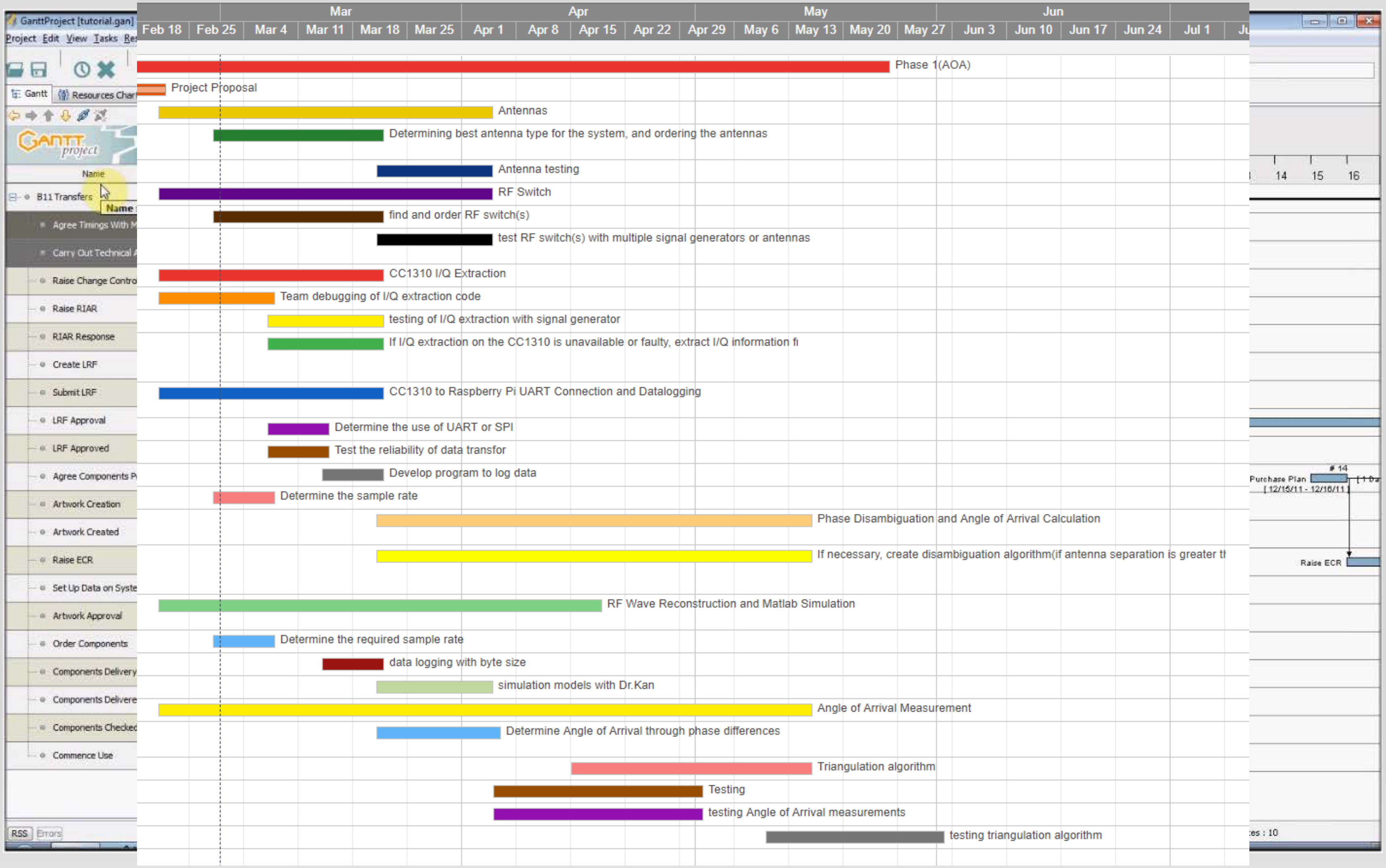
Average **error** of AOA

vs.

Range, noise, antenna separation, sample rate, carrier frequency, etc.



Management plan: GanttProject software



Deliverables ≠ weekly reports

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

General formatting

- Figures must be referred to in the text (not orphaned)!
- Figures should be labelled correctly
- Clarity!
    - Example: Ambiguity (*problem*) and disambiguation (*a solution process*) are not interchangeable

Where to go from here?

- Create list of "deliverables" including
  1. Specific system tests
  2. Hardware prototypes
  3. Simulation results
- Review literature for answers to specific design considerations and choices
  1. Literature review
  2. Technical approach
- Dr. Kan and his students have researched existing designs, written about them (see their literature reviews), and improved upon them. Go to him/them with **specific questions** about design considerations (E.g. What RF switch to use? Is an SDR a better choice than the CC1310? How fast must we sample? Etc.)