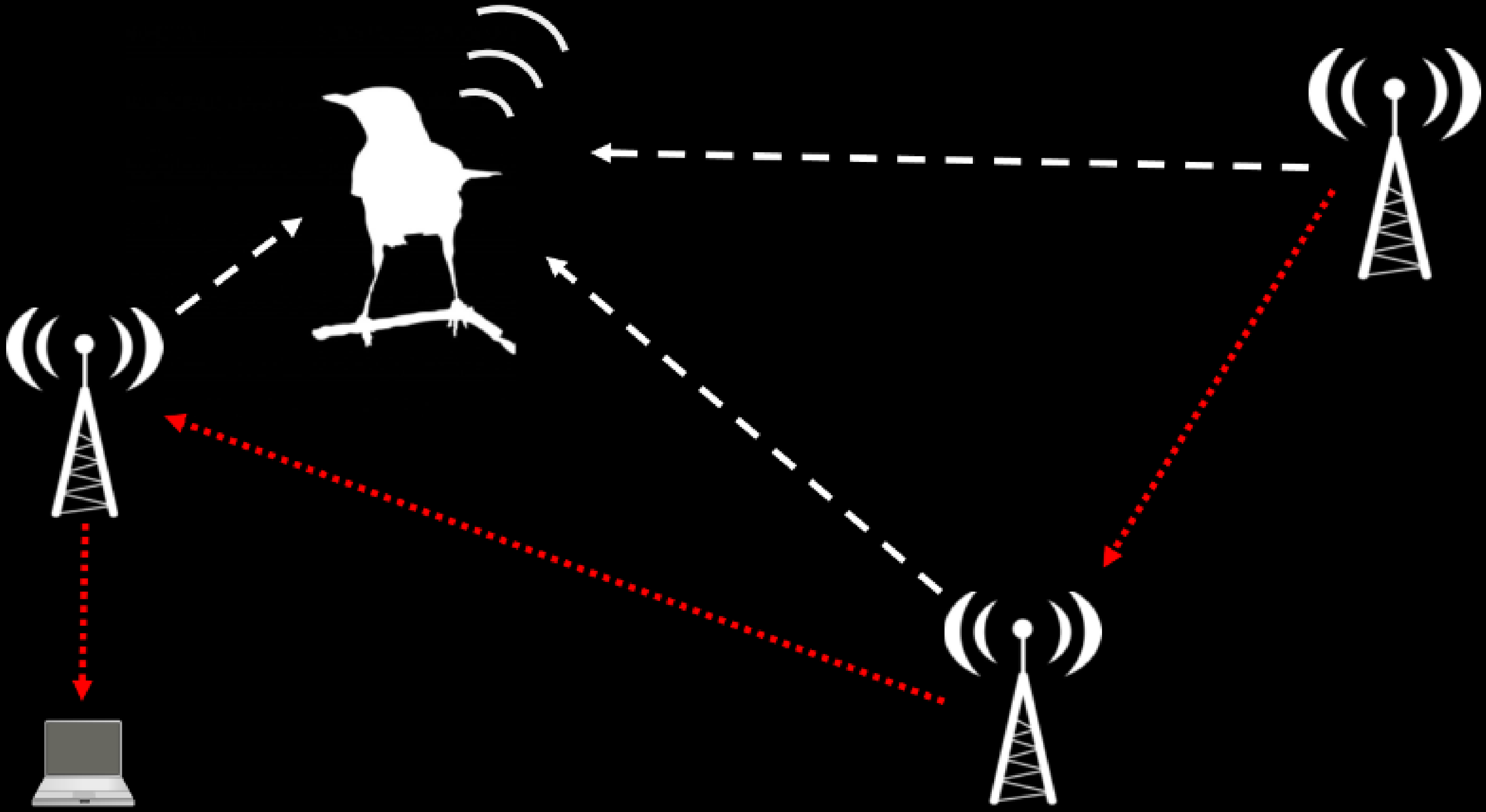
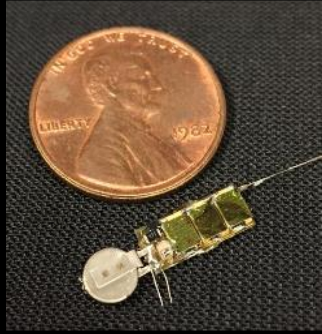
AMRUPT

(Animal Movement Research Using Phase-based Trilateration)





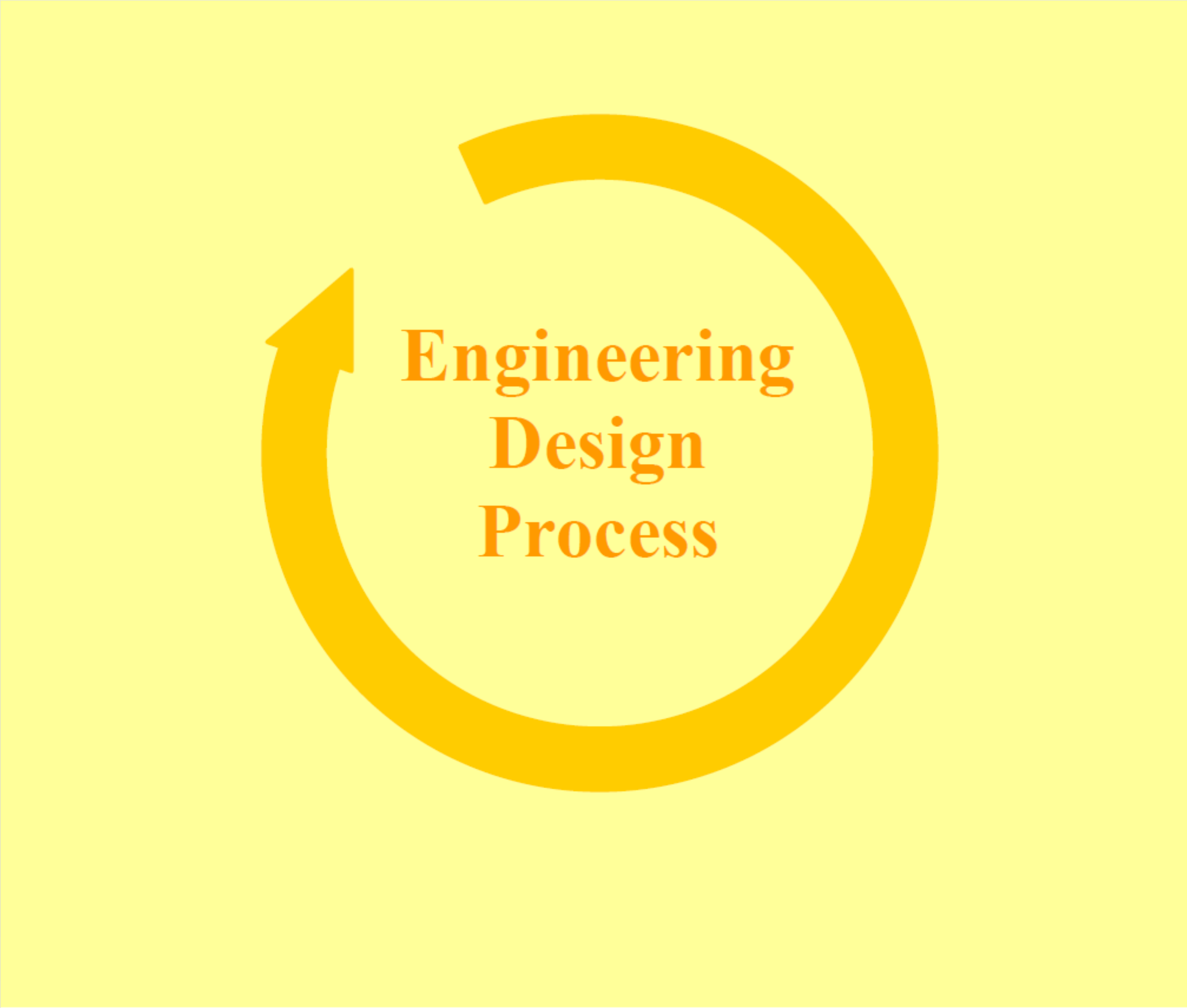
This week

1. "Engineering design process"
2. AMRUPT project consultation

Obtain pertinent information for generating a proposal for this semester's work.

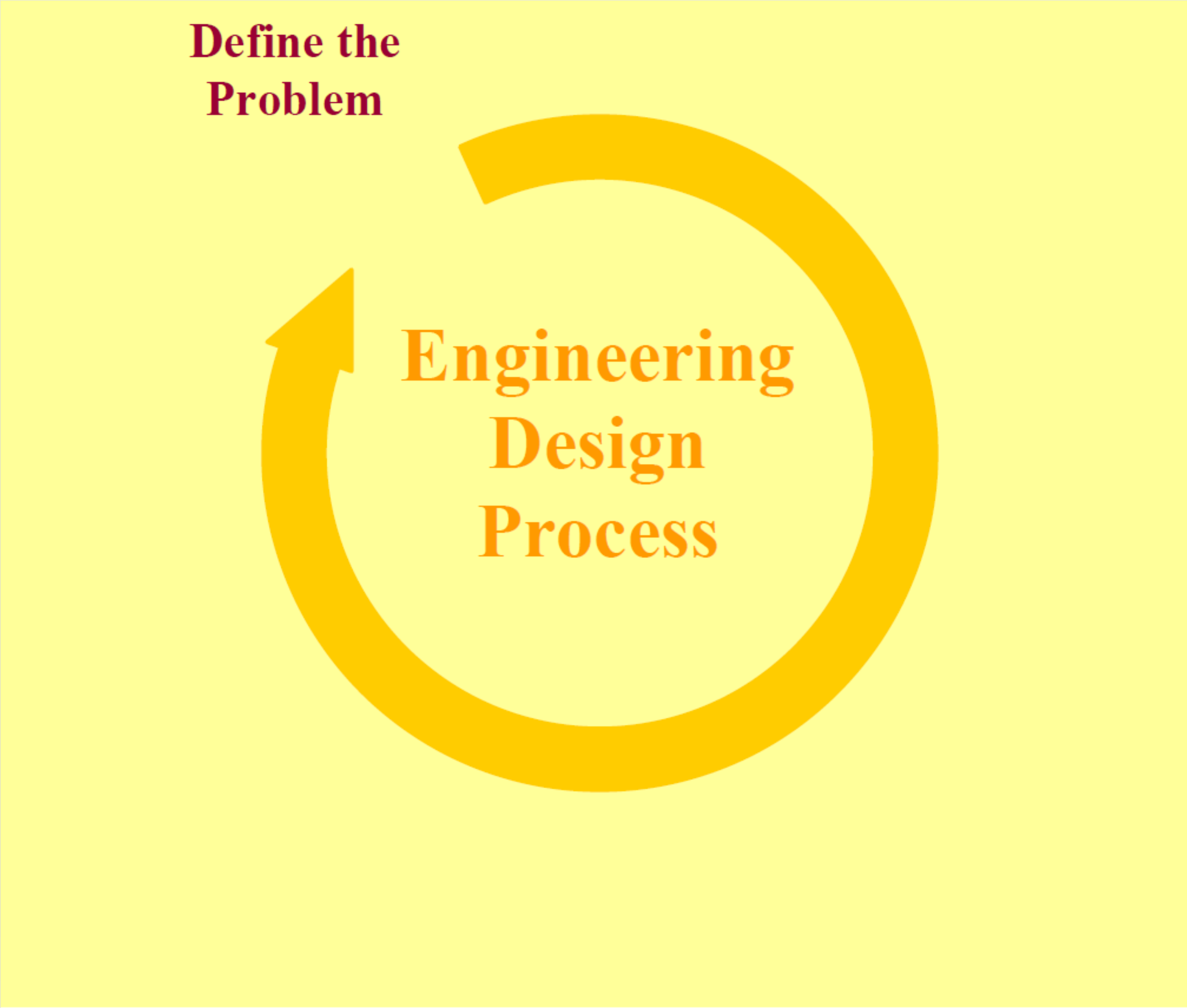
1. Generate list of questions to help you <u>define the problem</u>, and to <u>gather background information</u>

Step 1: Begin planning for the design process



Khandani, 2005

Step 1: Begin planning for the design process



Khandani, 2005

Define the problem

1. Identify and establish the need

"A common tendency is to begin generating a solution to an apparent problem without understanding the problem."

2. Develop a problem statement

"To reach a clear definition, [engineers] *collect data*, *run experiments*, and *perform computations* that allow a need to be expressed as part of an engineering problem-solving process."

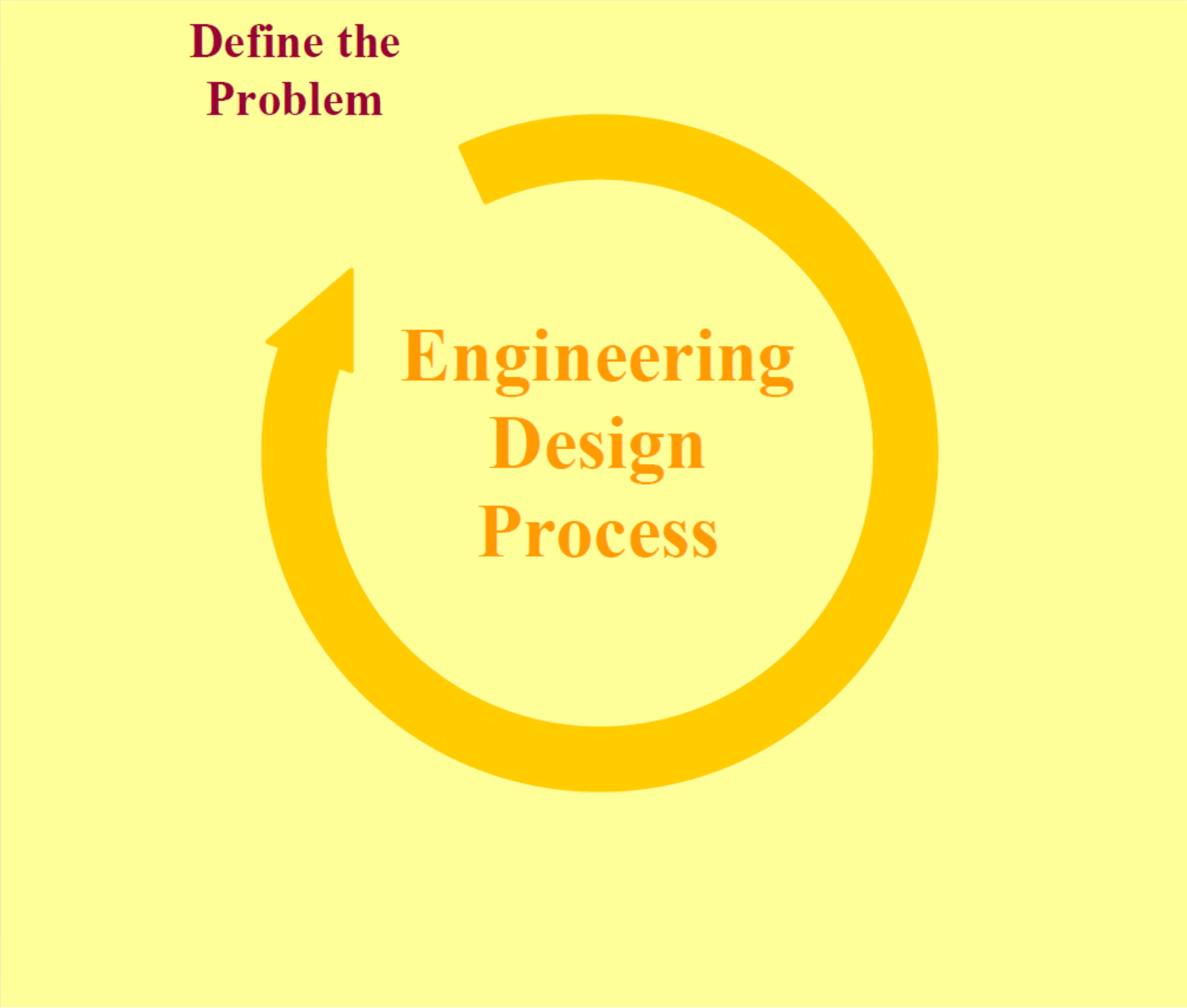
3. Establish explicit criteria for success

- The design must collect *accurate* data.
- The design must collect sufficiently *precise* data.
- The design must be *fast*.
- The design must be *low cost*.
- The design should be *safe*.
- The design should be *simple* to operate, with minimum human effort.

Requirements and constraints

1. **Short range:** *150m min, 300 m ideal, between receivers*
2. **Extremely simple transmitter design:** *lightweight (150 mg ideal, 300 mg upper limit), low power*
3. **Data sample rate:** *<5s interval ideal, 10s upper limit*
4. **Datalogging / data management:** *each receiver must receive data from ~20-50 tags at 5s interval each for 1 day, data must be uploaded to central hub automatically, physical retrieval from hub can occur daily , triangulation need not occur before data is retrieved, can use cellular networks*
5. **Duration of datalogging:** *system should remain operational 3-4 months*
6. **GUI:** *not needed for visualizing bird locations, but need a way to identify system operation status either from the hub or from each ground-node*
7. **System can operate in cluttered environments:** *multipath interference*
8. **Number of mobile nodes:** 50 adequate, upper limit of 1000 for total # deployed; expect only 0-20 mobile-nodes to be within range of a given ground-node at a time
9. **High spatial accuracy for triangulation results:** *~5 m*
10. **Low cost receivers:** *COTS components*
11. **Low power consumption of receivers:** *can operate on solar power*
12. **2D localization (lat,long) OK, 3D (lat,long,azimuth) ideal**
13. **Communication protocol:** *Time division multiplexing (not frequency) to maximize Tx sleep modes*
14. **Forward compatibility:** *Must be compatible with and adaptable to a multi-frequency-phase-integer-disambiguation approach for future versions*

Engineering design process



Khandani, 2005

Gather pertinent information

1. Refine your thinking about the problem, and place it in context

- Is the problem real and its statement accurate?
- Is there really a need for a new solution or has the problem already been solved?
- What are the existing solutions to the problem?
- What is wrong with the way the problem is currently being solved?
- What is right about the way the problem is currently being solved?

2. Search for information sources

- Scientific encyclopedias and technical handbooks.
- Primary articles
- Faculty in ECE and beyond
- Company websites and brochures

Gather pertinent information

Indoor Passive Device Ranging by Low-directivity Antennas with Centimeter Precision

Yunfei Ma, *Student Member, IEEE,* Xiaonan Hui, *Student Member, IEEE,* Pragya Sharma, *Student Member, IEEE,* and Edwin C. Kan, *Senior Member, IEEE*

Abstract—**Compared to the high-directivity patch and horn antennas, miniaturized omni-directional antennas allow more**

synthetic aperture radar (ISAR) techniques to form a large

3D Real-time Indoor Localization via Broadband Nonlinear Backscatter in Passive Devices with Centimeter Precision

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ABSTRACT

ror was 3.5 *cm* in the indoor environment. Presently, the

Press escape to exit fullscreen mode

IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, VOL. 62, NO. 5, MAY 2014 1249

Accurate Indoor Ranging by Broadband Harmonic Generation in Passive NLTL Backscatter Tags

Yunfei Ma, *Student Member, IEEE*, and Edwin Chihchuan Kan, *Senior Member, IEEE*

Abstract—**Millimeter-precision meter-distance real-time indoor ranging capability is challenging due to multipath reflections in a rich scattering environment. Traditional continuous wave (CW) phase-based ranging methods, although simple and flexible, are vulnerable to phase offsets and interferences. We improve the previous CW approach by passive broadband harmonic non-linear-transmission-line (NLTL) tags. Since phase information is now contained within the second harmonic rather than the fundamental frequency, interferences and phase errors caused by direct reflections of the interrogating signal are greatly reduced. By the broadband property of NLTL, a heuristic multi-frequency CW method is formulated to resolve the phase integer ambiguity and to further improve ranging accuracy and robustness even under large phase errors. We present theoretical and simulation analyses, followed by experimental verification.**

reader attempts filtering out these interferences as dc offset after demodulation, but has the following difficult issues.

1) Large interference can cause a jamming problem in receivers without sufficient dynamic range.
2) Phase noise in unknown interferences raises the noise floor dramatically, which decreases receiver sensitivity and limits the reading range [10].
3) As the input power level at the receiver approaches the 1-dB compression point, the phase shift in the receiving channel becomes more power dependent due to nonlinearities, which makes phase offset calibration difficult [11].
4) In an environment with moving scatterers such as the

1590 IEEE TRANSACTIONS ON AUTOMATION SCIENCE AND ENGINEERING, VOL. 14, NO. 4, OCTOBER 2017

The Optimization for Hyperbolic Positioning of UHF Passive RFID Tags

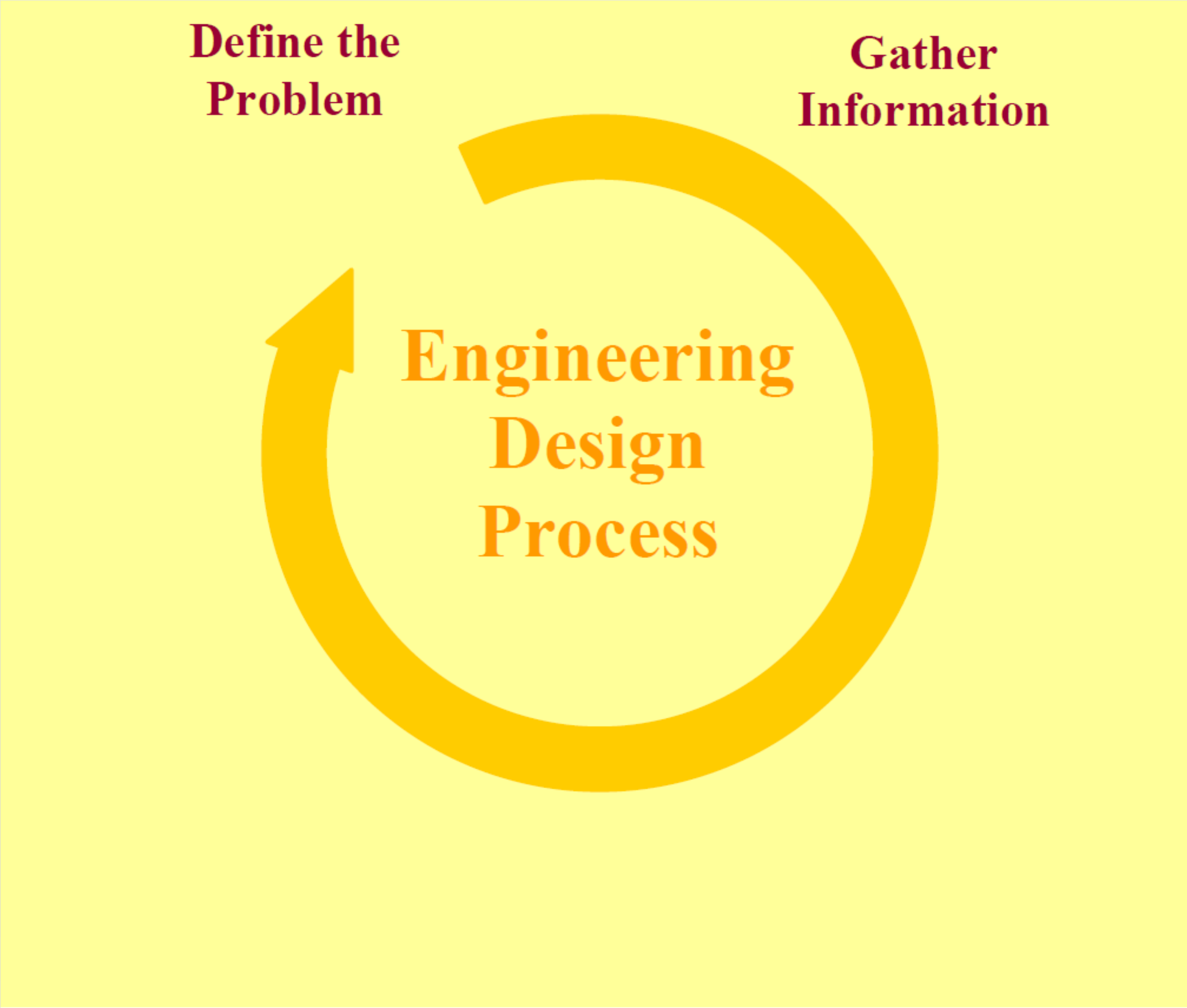
Haishu Ma, Yi Wang, Kesheng Wang, and Zongzheng Ma

Abstract—**This paper presents a fine-grained positioning method for radio frequency identification (RFID). The proposed method applies hyperbolic positioning to locate ultrahigh frequency passive RFID tags. In our design, finding the tagged object's location is formulated as an optimization problem. Phase values, collected by the moving antenna, are exploited to achieve the optimal solution. The intuition of hyperbolic positioning lies in that the difference of distances from a target tag to two antennas can be inferred from phases. When integrating hyperbola curves together, optimization method can be performed to achieve the object's location. Particle swarm optimization is then applied to enhance computational ability. For random phases, polynomial regression is employed to model the relationship between phase values and distances. We implement a prototype of hyperbolic positioning optimization to pinpoint the RFID tag's location**

I. Introduction

RADIO frequency identification (RFID) has been widely adopted in supply chain management and warehousing for the purpose of automatic identification and tracking of objects. A typical RFID system is made of tags, reader, and antenna. RFID reader can communicate with the tag in an electromagnetic field. Whenever a tag enters the interrogation region, it can be detected by the RFID reader [1]. Depending on the power output of reader and the types of tag, the read range of RFID system can be as far as tens of meters [2]. Under many circumstances, it is not enough to only identify whether the RFID-tagged object is within the read range. For example, a robot arm can reach for a target object, pick it

Engineering design process



Khandani, 2005

Generate multiple solutions

Synthesize ideas from existing work

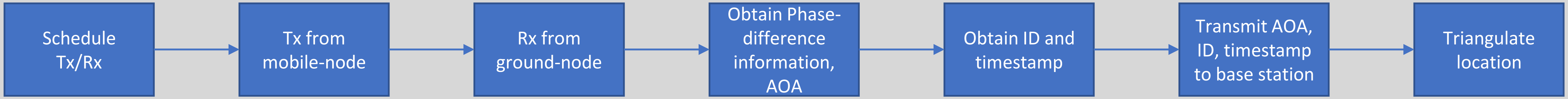
- "Start with existing solutions to the problem and then tear them apart to find out what's wrong with those solutions and focus on how to improve their weaknesses."

Brainstorming important!!

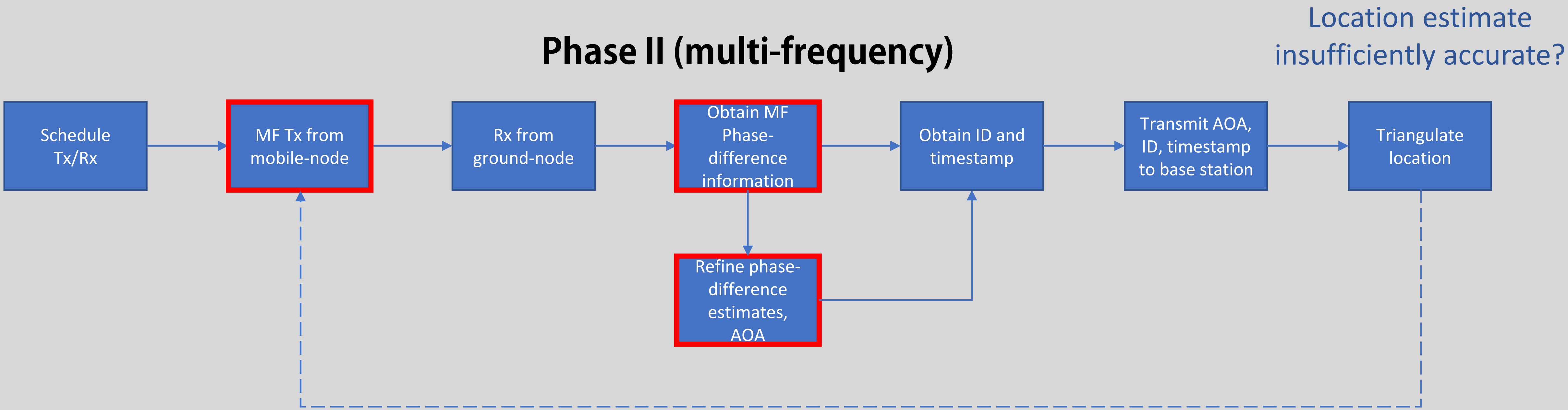
- "Ideas are generated when people are free to take risks and make mistakes."
- "Brainstorming at this stage is often a <u>team effort</u> in which people from <u>different disciplines</u> are involved in generating multiple solutions to the problem."

3 tiered approaches (phases)

Phase I (single frequency)

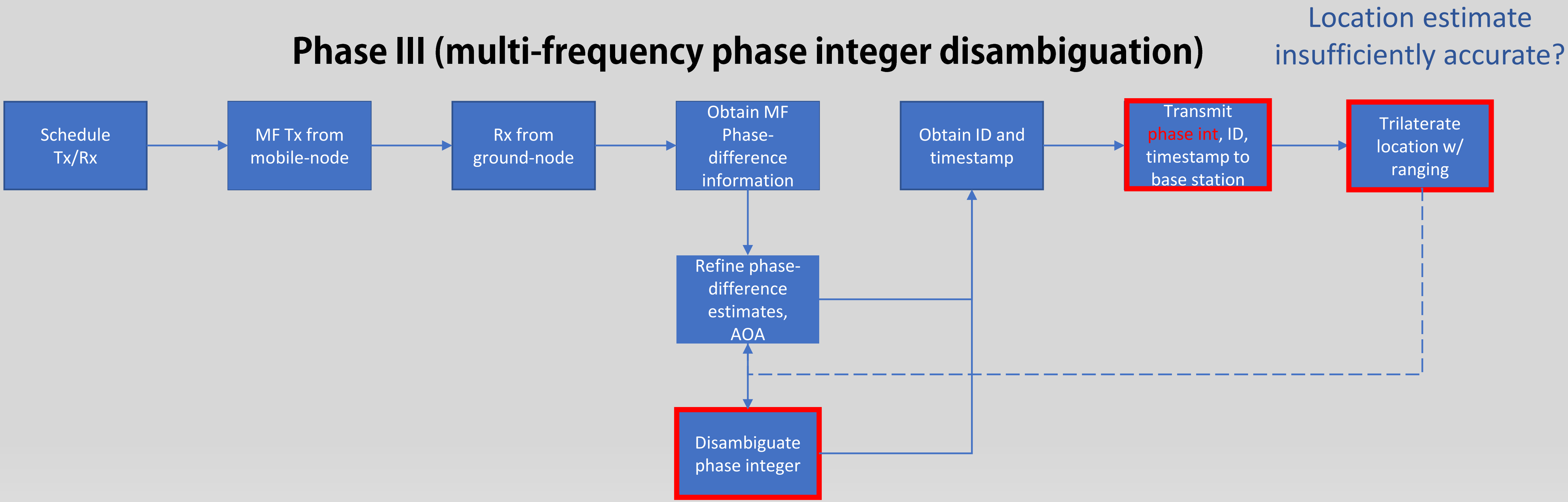


3 tiered approaches (phases)

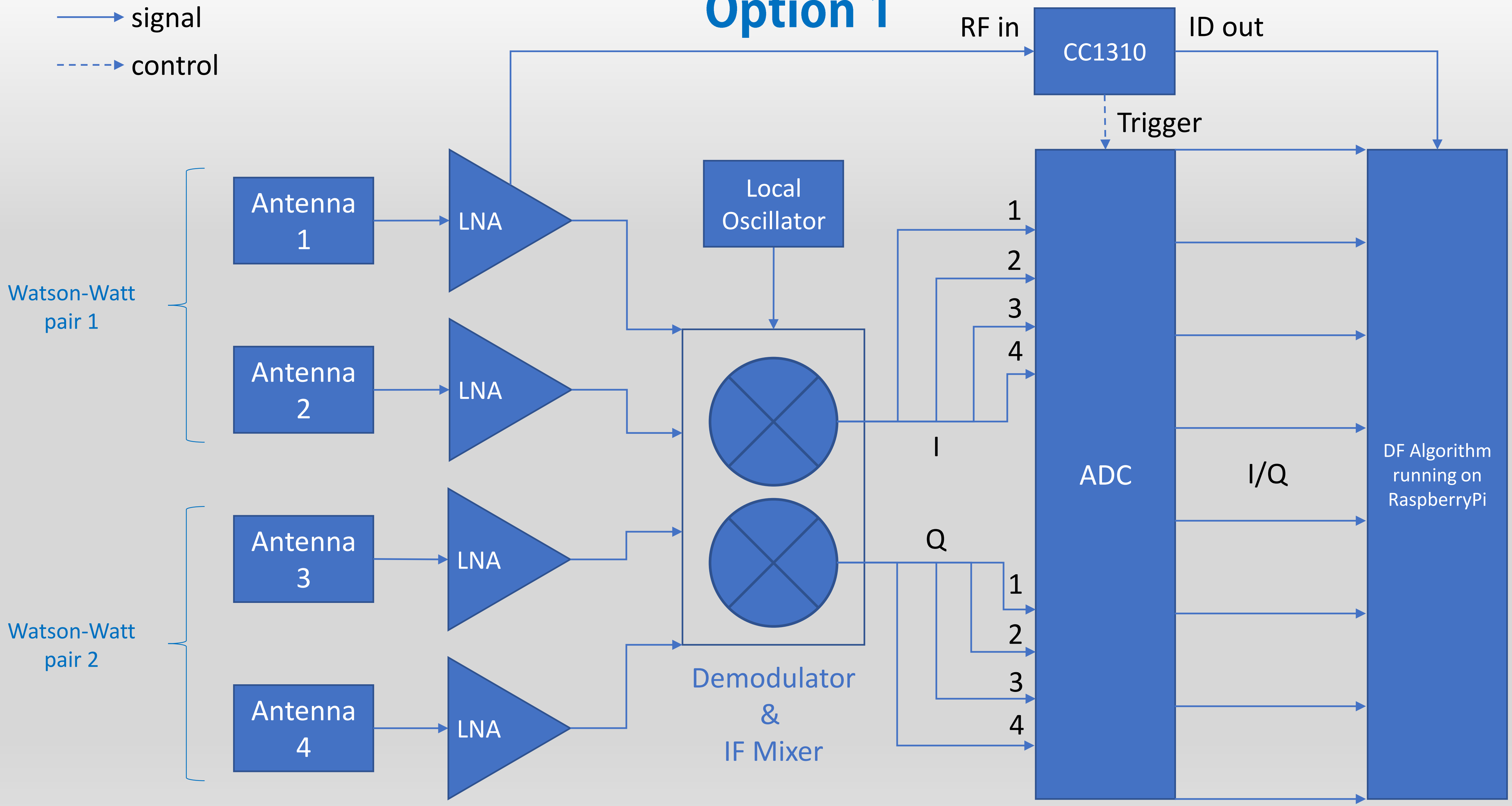


3 tiered approaches (phases)

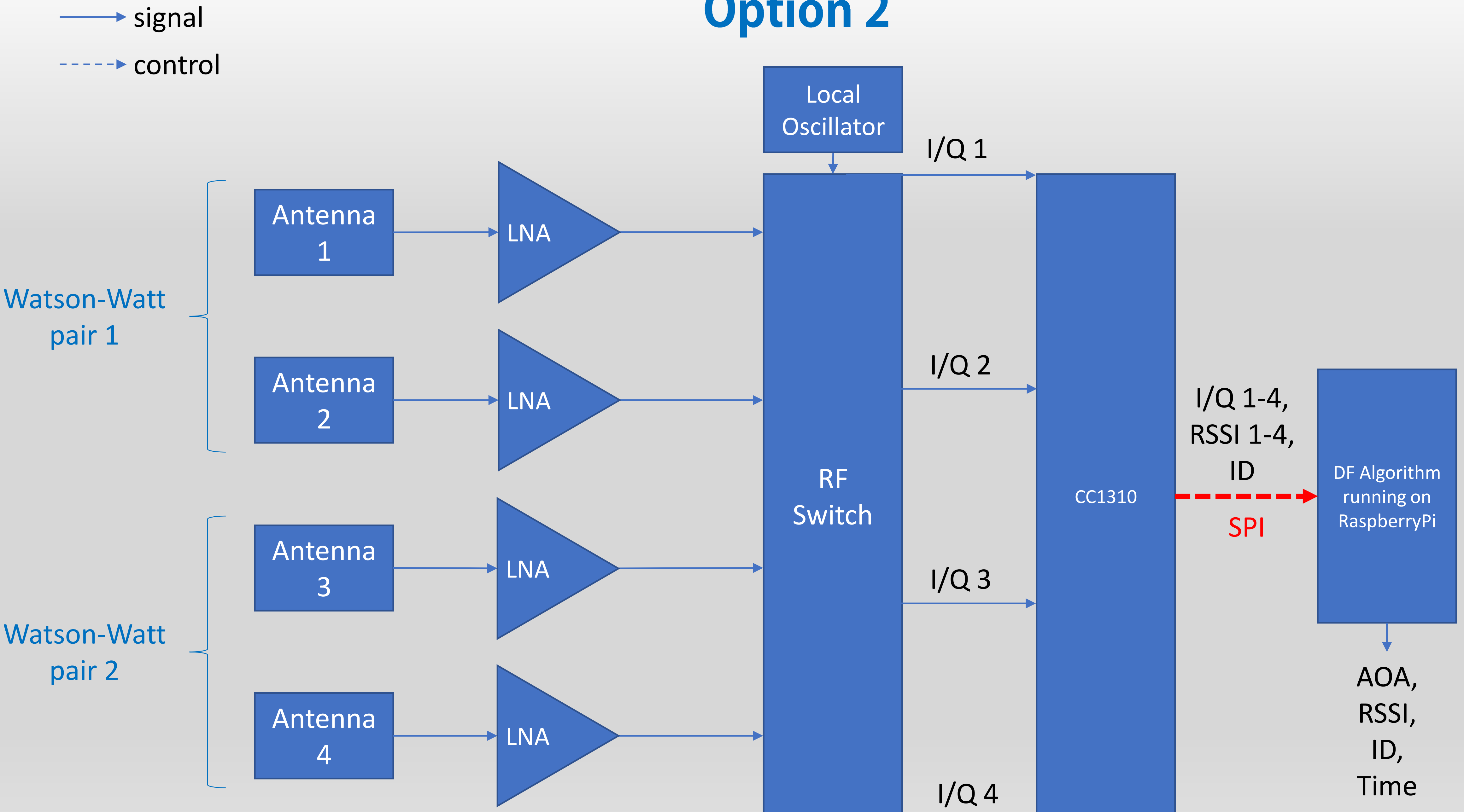
Phase III (multi-frequency phase integer disambiguation)



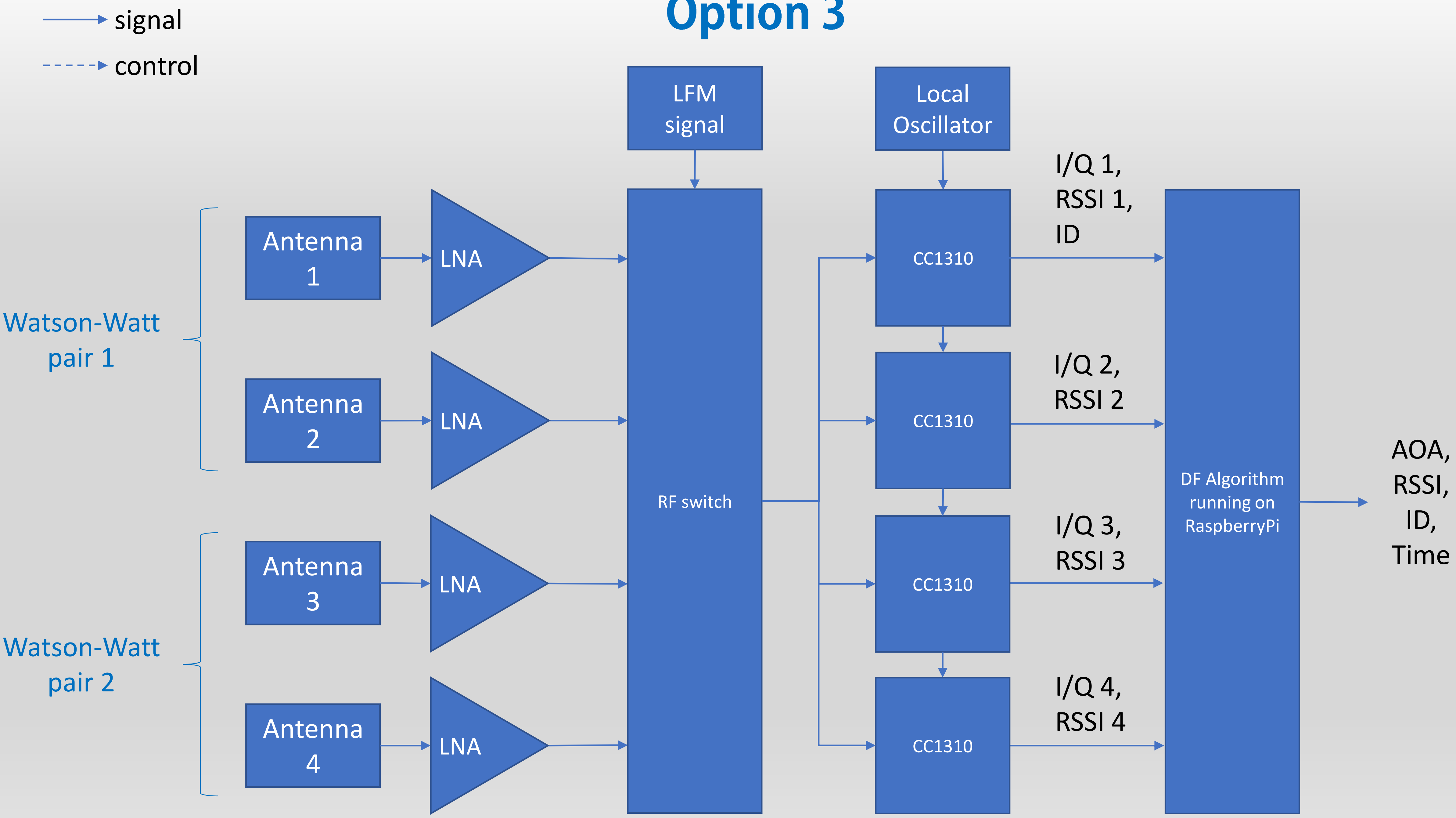
Option 1

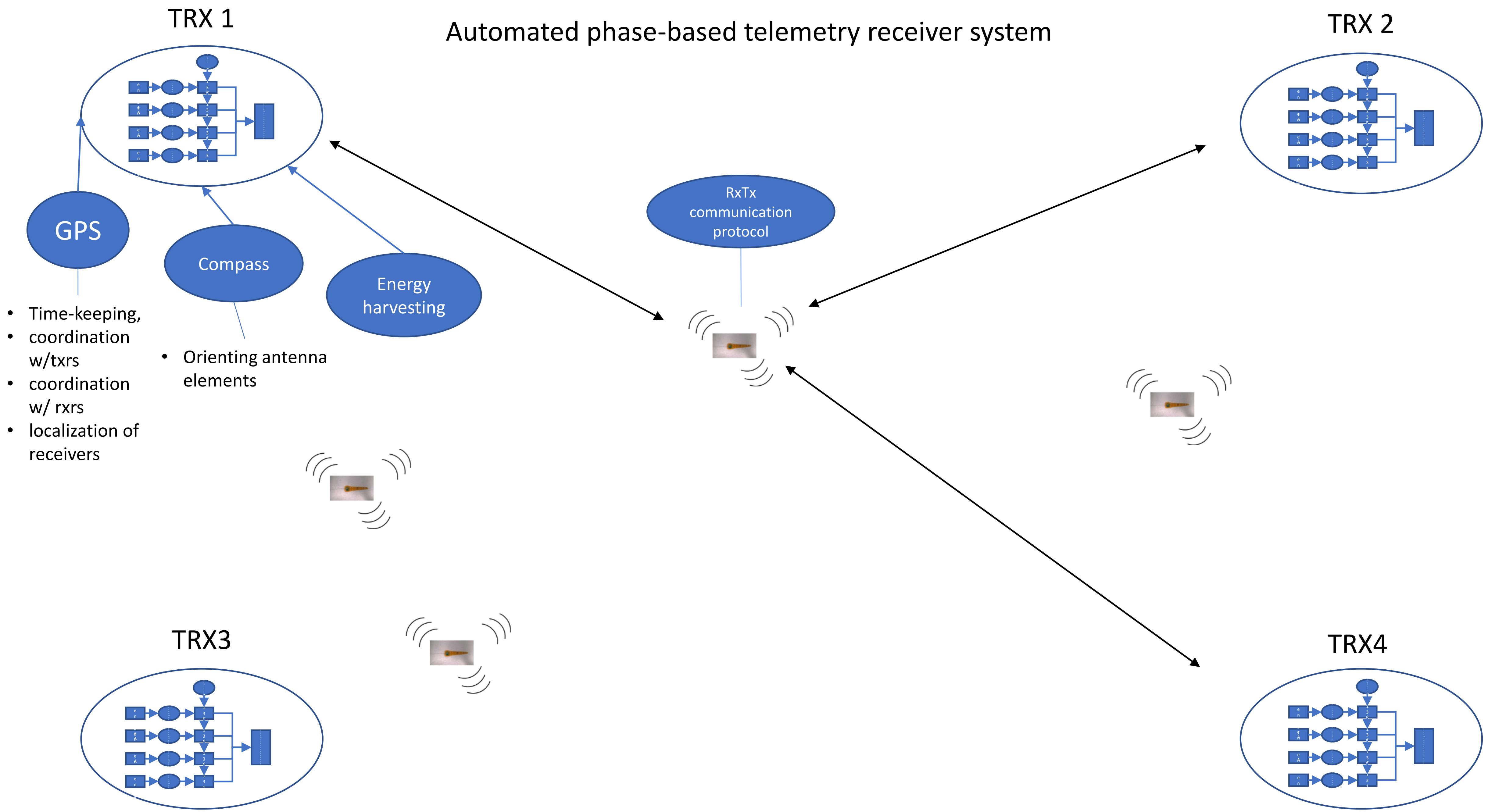

signal
control
RF in
CC1310
ID out
Trigger
Watson-Watt pair 1
Watson-Watt pair 2
Antenna 1
Antenna 2
Antenna 3
Antenna 4
LNA
LNA
LNA
LNA
Local Oscillator
Demodulator & IF Mixer
I
Q
1
2
3
4
1
2
3
4
ADC
I/Q
DF Algorithm running on RaspberryPi

Option 2

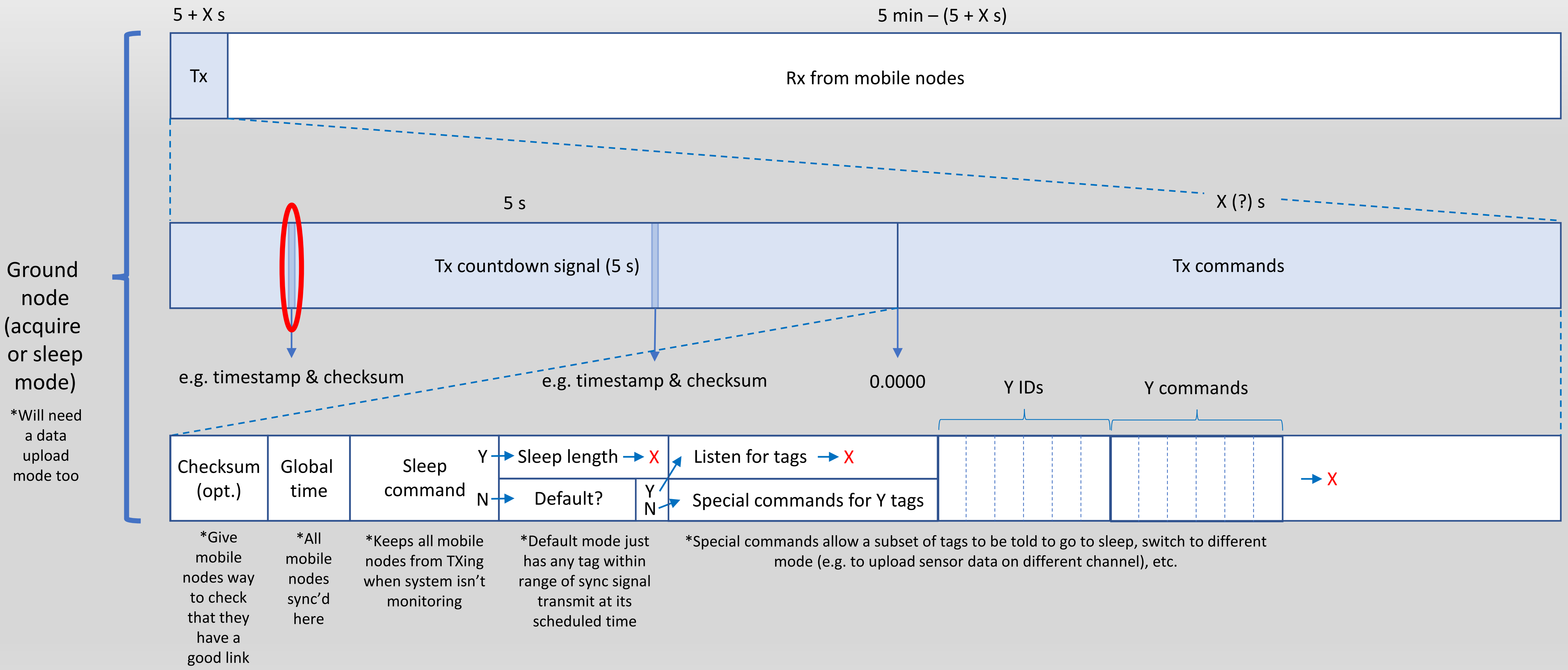

signal
control
Local Oscillator
Watson-Watt pair 1
Watson-Watt pair 2
Antenna 1
Antenna 2
Antenna 3
Antenna 4
LNA
LNA
LNA
LNA
RF Switch
I/Q 1
I/Q 2
I/Q 3
I/Q 4
CC1310
I/Q 1-4, RSSI 1-4, ID
SPI
DF Algorithm running on RaspberryPi
AOA, RSSI, ID, Time

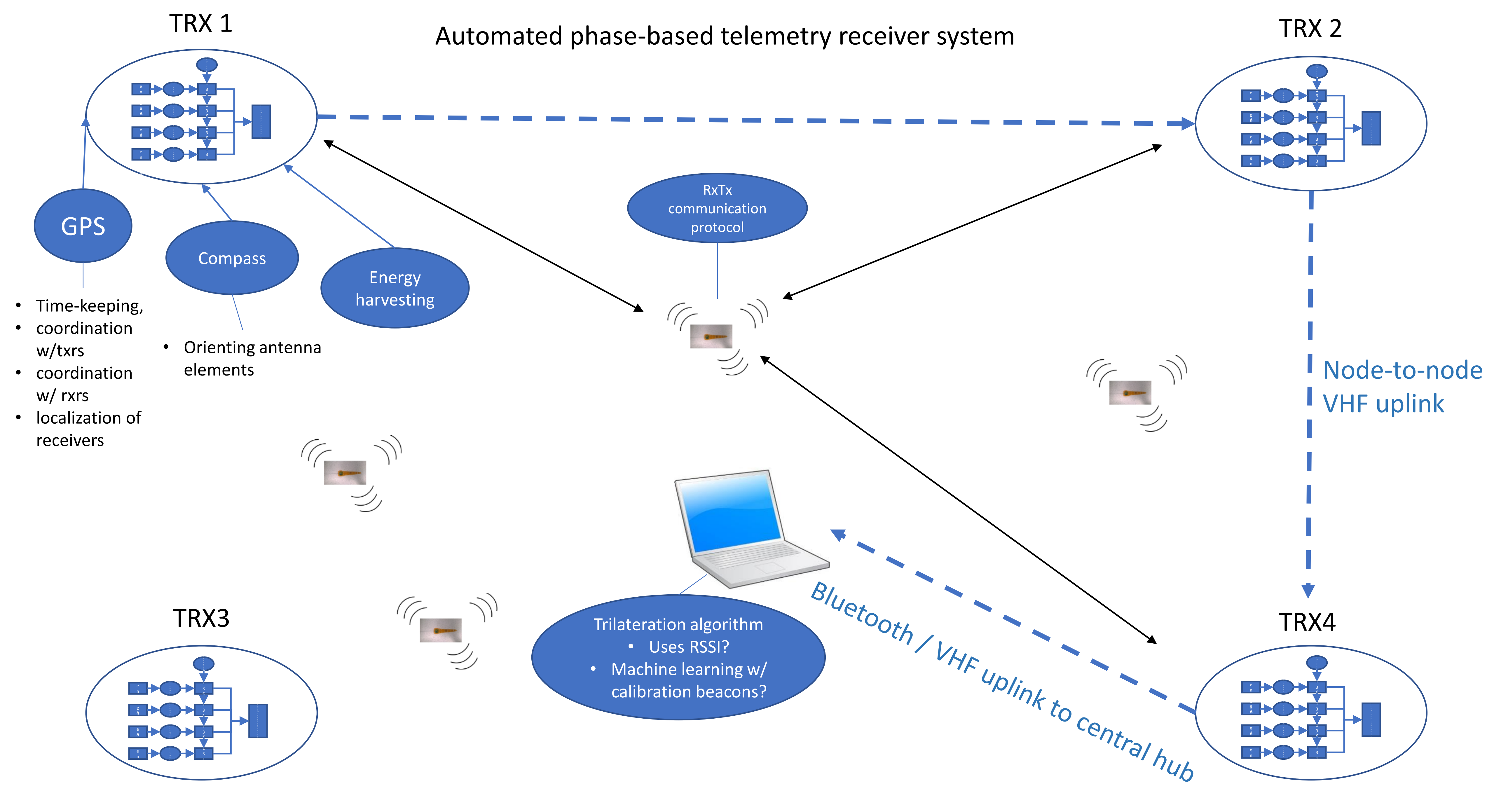
Option 3


signal
control
LFM signal
Local Oscillator
Watson-Watt pair 1
Antenna 1
Antenna 2
Watson-Watt pair 2
Antenna 3
Antenna 4
LNA
LNA
LNA
LNA
RF switch
CC1310
CC1310
CC1310
CC1310
I/Q 1, RSSI 1, ID
I/Q 2, RSSI 2
I/Q 3, RSSI 3
I/Q 4, RSSI 4
DF Algorithm running on RaspberryPi
AOA, RSSI, ID, Time


Automated phase-based telemetry receiver system
TRX 1
TRX 2
TRX3
TRX4
GPS
Compass
Energy harvesting
RxTx communication protocol
• Time-keeping,
• coordination w/txrs
• coordination w/ rxrs
• localization of receivers
• Orienting antenna elements

Mobile-to-Ground Node Communication Protocol

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• Time-keeping,
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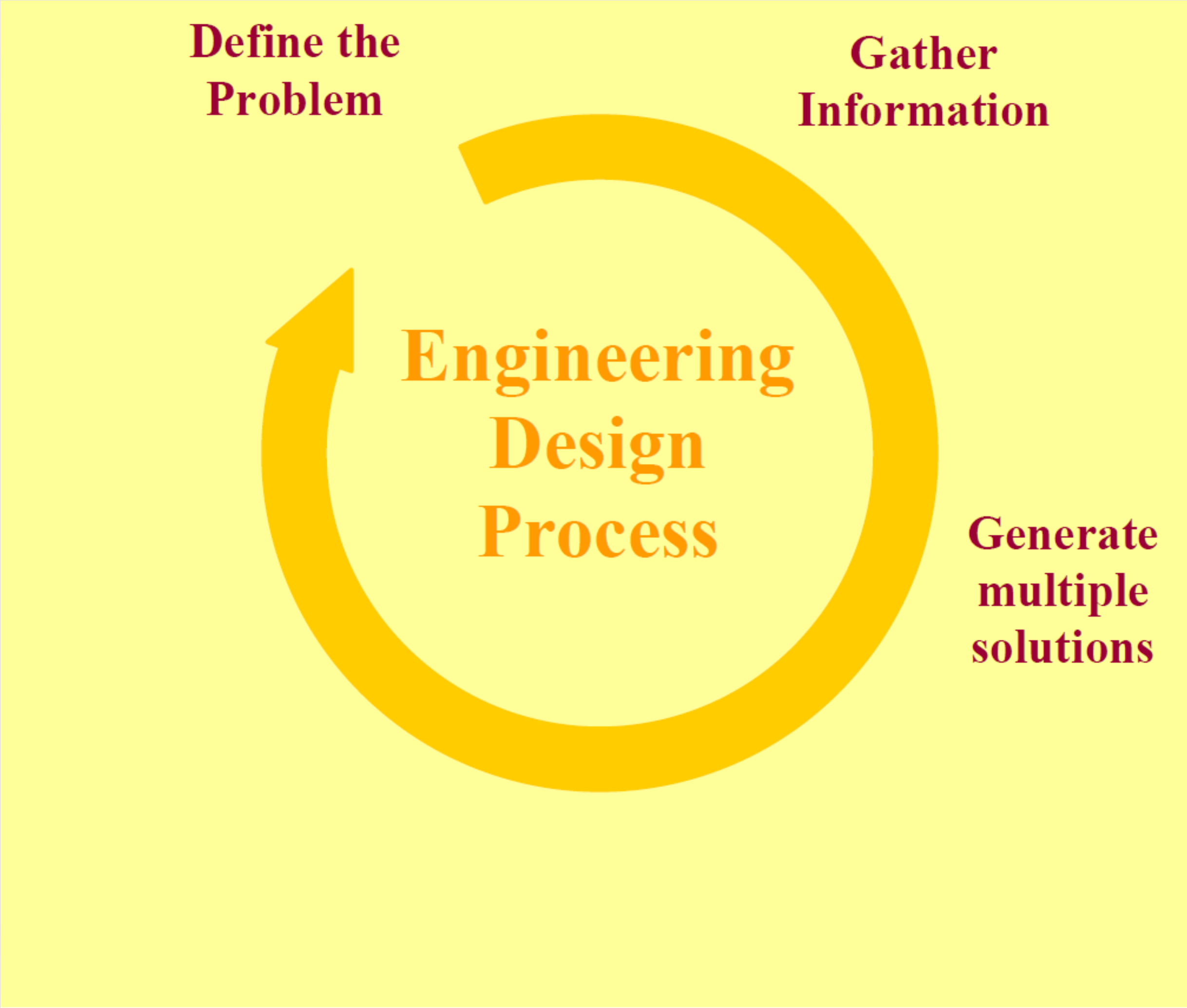
• localization of receivers
Compass
• Orienting antenna elements
Energy harvesting
RxTx communication protocol
Node-to-node VHF uplink
Trilateration algorithm
• Uses RSSI?
• Machine learning w/ calibration beacons?
Bluetooth / VHF uplink to central hub

Engineering design process



Khandani, 2005

Analyze and select a solution

1. Systematic analysis of design solutions

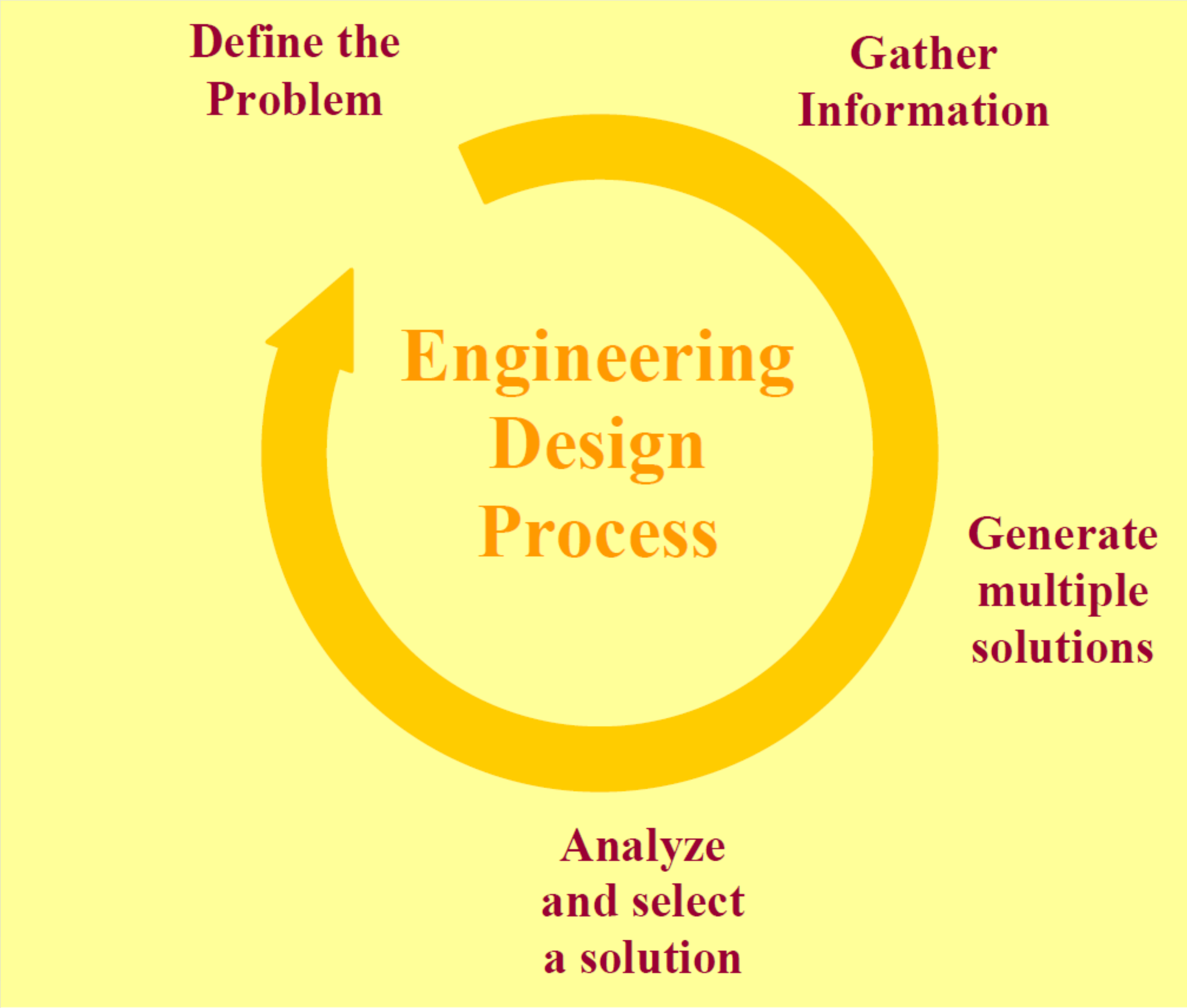
- Functional analysis – **will it function the way it should?**
- Mechanical/Strength analysis – **is it physically durable?**
- Manufacturability/Testability – **can it be produced easily? Is it overly complex?**
- Product safety and liability – **will it be safe for the user?**
- Economic and market analysis – **is it affordable / cost-effective?**
- Regulatory and Compliance – **is it legal (think about FCC regulations)?**

2. The decision process: how to choose among the options?

- Think about using a decision matrix:
  - Functionality: 30 %
  - Cost: 20 %
  - Complexity: 20 %
  - Safety: 20 %
  - Use of standard parts: 10 %

A	B	C
25	30	15
20	15	20
10	20	20
20	20	20
5	10	5
80	**95**	**80**

Engineering design process



Khandani, 2005

Test and implement the solution

1. Prototyping

- **Simulations** and **simplified models** to evaluate if you're on the right track. Help define what other considerations may be need to be met before getting too far.

2. Documentation (!!!!)

- "One of the most important activities in design is documenting your work, clearly communicating the solution to your design problem so someone else can understand what you have created."

Good documentation is essential!

In-line comments

```r
#' Create a complete ggplot appropriate to a particular data type
#'
#' \code{autoplot} uses ggplot2 to draw a particular plot for an object of a
#' particular class in a single command. This defines the S3 generic that
#' other classes and packages can extend.
#'
#' @param object an object, whose class will determine the behaviour of autoplot
#' @param ... other arguments passed to specific methods
#' @return a ggplot object
#' @export
#' @seealso \code{\link{ggplot}} and \code{\link{fortify}}
autoplot <- function(object, ...) {
  UseMethod("autoplot")
}
```

“ReadMe” file

Project Title

One Paragraph of project description goes here

Getting Started

These instructions will get you a copy of the project up and running on your local machine for development and testing purposes. See deployment for notes on how to deploy the project on a live system.

Prerequisites

What things you need to install the software and how to install them

```
Give examples
```

Installing

A step by step series of examples that tell you have to get a development env running

Say what the step will be

```
Give the example
```

And repeat

```
until finished
```

End with an example of getting some data out of the system or using it for a little demo

Running the tests

Explain how to run the automated tests for this system

Break down into end to end tests

Explain what these tests test and why

```
Give an example
```

Test and implement the solution

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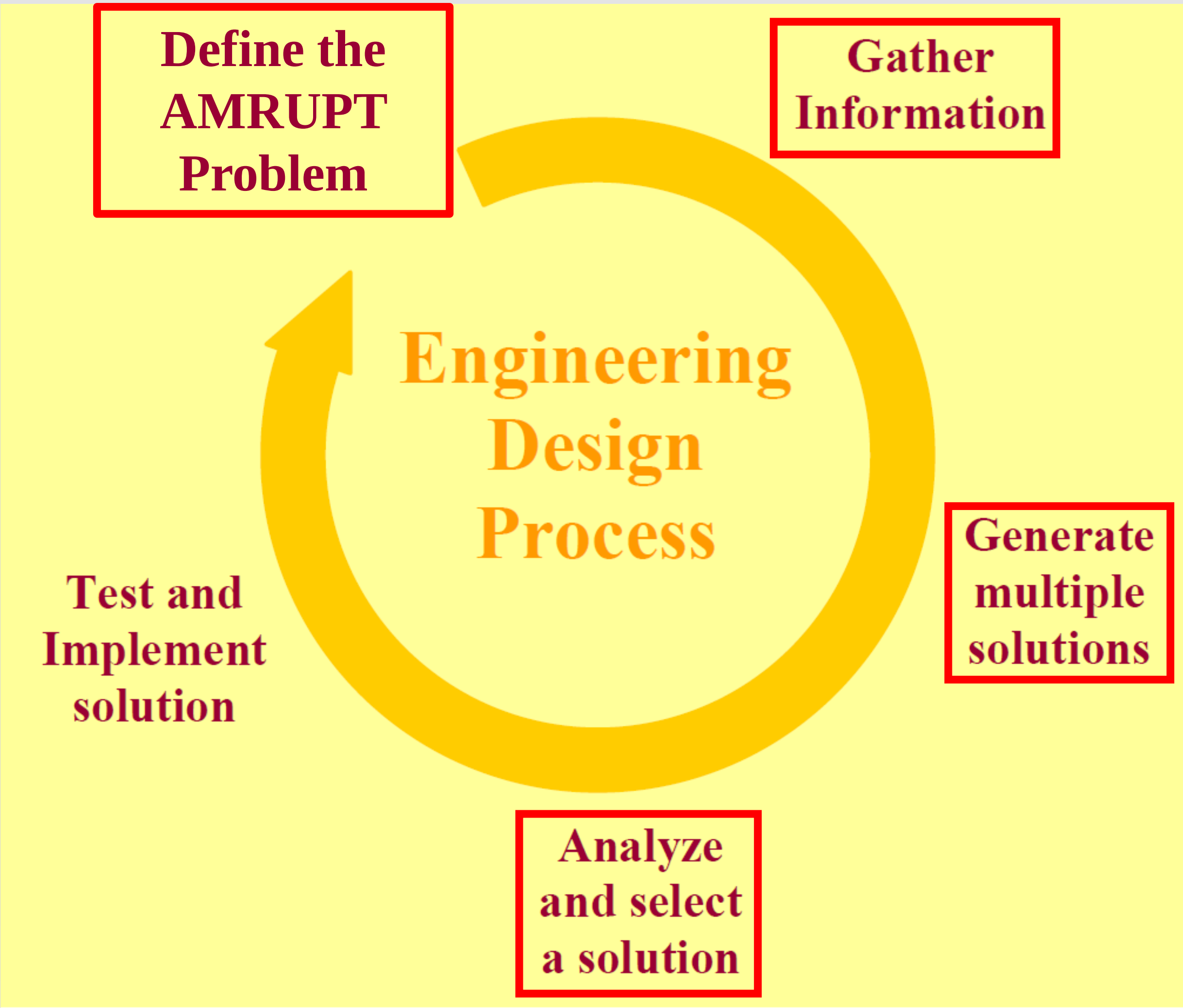
- "One of the most important activities in design is documenting your work, clearly communicating the solution to your design problem so someone else can understand what you have created."

3. Testing and verification

- Without proper testing at all stages in the process, **you may find yourself making costly mistakes later.**
- **Standardized test sets** to evaluate functionality across semesters

Engineering design process



Khandani, 2005

Project Proposal