

# Design, Development and Delivery of a Radar Capability Development Program

*MILSIM 2020*  
*Singapore*

**LEE Kar Heng**



# Acknowledgement

- The authors are thankful to the organizing committee for the opportunity to speak at the conference
- The speaker is gratified to ***all the reviews and inputs*** given to improve this presentation
- The speaker is thankful to the Participants in the usage of some information

# Engineerpreneur

*“A good engineer is one who is skillful enough to problem practical problems by dirtying his or her hands, as well as knowledgeable enough to address other professionals in conferences or symposiums.” (K.H. Lee)*

*“A successful entrepreneur is one who takes the risk to start up a business, provides unique services or products with his or her skill and knowledge so as to generate an income to substitute a salary.” (K.H. Lee)*

- Engineerpreneur (founder and director of TBSS Center for Electrical and Electronics Engineering ,Singapore) and Cong Ty TNHH Cong Nghe va Giam Sat RADAR TBSS, Vietnam)
- Ex-civil servant (Temasek Polytechnic, ITE, MHA, DSTA, DSO, MPA, RSN)
- Ex-lecturer (SIM University, University of Newcastle, Edith Cowan University, TP, ITE, RMIT, University of Southern Queensland and Northumbria University)
- Practising Engineer, Engineer by training and education (Ph.D, M.Eng, M.Sc, B.Tech, Diploma)
- Presented close to 30 papers at international conferences/journals (USA, China, Hong Kong, Maldives, South Africa, Switzerland, France, Malaysia, Dubai, Singapore, Vietnam, Philippines)
- School Advisory Committee of Henry Park Primary School, Past Chairman of IEEE Education Chapter, **Founding President of AOC Singapore Chapter**, Advisor of Vietnamese Chamber of Commerce Singapore, Senior Advisor of Vietnamese Association in Singapore

*I am an Engineer, I am also an Entrepreneur, therefore I am an Engineerpreneur.*



# The Program Objectives

# Training Objective

- To build up the capability of a specific group of radar engineers and academics from an ASEAN country
  - Radar signal processing
  - Radar display
- Deliverables
  - build a test FMCW radar to demonstrate the capability of the participants
- Requires
  - customized courses
  - equipment and development kits
  - display software
  - hardware



# Program Formulation

- Alignment of expectations
  - meetings, emails, Whatsapp correspondence
- Outcome
  - the RCDP which comprises of customised courses, acquisition of relevant hardware and software, project supervision



Working Meal



Initial Meeting to Understand the Program Requirements

# The Program

- This RCDP covers
  - training to build up technical capability and provision of guidance
  - construct a FMCW radar which includes design, testing and measurement and prototyping in an agreed time frame
  - documentation:
    - Program Management Plan (PMP)
    - Training Management Plan (TMP)
    - System Design Document (SSD)
    - Test and Measurement Document (TMD)

# Roles and Responsibilities



# Involving the Top Management

- It is necessary to involve the top management of the participants to ensure the program is implemented efficiently and effectively
  - To identify the officers for the program
  - To monitor the program progress
  - To approve the project plan
  - To ensure that the program participants work diligently
  - To attend meetings with progress meetings

# Participants' Responsibilities

- The participants are required to demonstrate their ability
  - to *integrate* fundamental knowledge into developing techniques, methods and *analyses* in the process of completing the project
- They are also required to take initiative such as *recommending alternative solutions* besides working as a team and also independently through exercising self-discipline, self-management and job coordination

# Participants' Responsibilities

- The responsibilities of participants are as follows:
  - To produce the a working product according to the specified requirements
  - To schedule meetings with Program Management Team
  - To adhere to the meeting scheduled for the purpose of updating progress and seeking advice on project matters
  - To record progress activities of their project in a weekly log and compile it properly for record keeping using the Weekly Report Log
  - To submit weekly log

# Participants' Responsibilities

- The responsibilities of participants are as follows:
  - To be responsible in finding alternative solution for problems encountered such as computer crashes and instrument failure
  - To submit all required logs and reports on time with no exception
  - To update Program Management Team
  - Daily Work Update Whatsapp Group
  - To submit monthly reports before the conduct of month meeting

# The Program

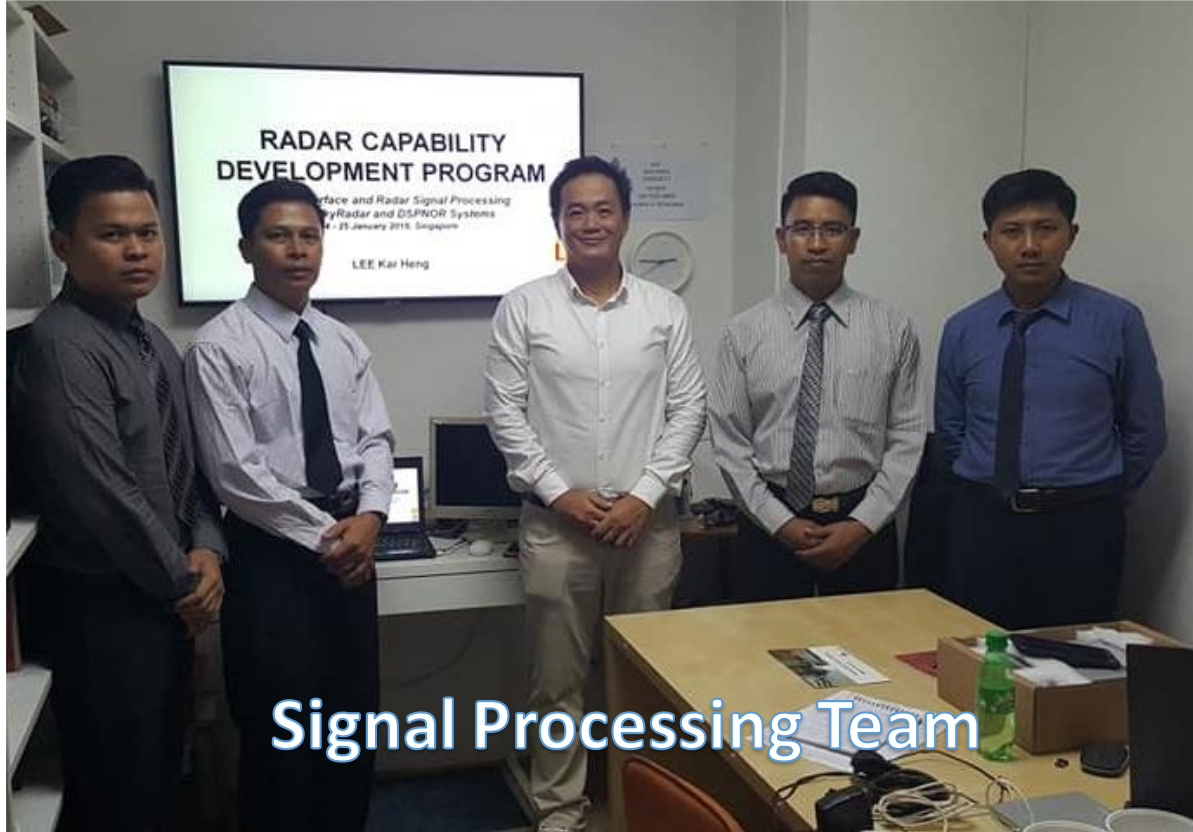


# Program Schedule

	Month 1	Month 2	Month 3	Month 3	Month 3	Month 5	Month 6	Month 7	Month 8	Month 9
Project Kick Start Meeting										
Training		█	█				█			
Laboratory Set Up	█	█								
Test Radar	█	█								
Finalize Design		█	█							
Radar Interface			█	█					█	█
Develop Signal Processing				█	█	█	█	█	█	
Testing						█	█	█	█	█
Documentation							█	█	█	█
Reports			█			█			█	█

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# The Participants



Signal Processing Team



Radar Display Design Team

# Training and Courses

- Participants attended all the scheduled training diligently
- All the course contents are entirely understood
- Completed the course feedback form for each course
- Completed a Training Report for each course
- The training conducted
  - Radar Interfacing and Signal Processing Techniques
  - FPGA for Radar Signal Processing
  - Radar Display Development.

# Development Work

- The participants prepared a workspace to develop the prototype radar
- The participants produced the design diagrams with inputs from the Program Management Team
- The capabilities to be developed are radar interfacing, radar signal processing and radar display
- The Top Management ensured that all the necessary supports are provided
- The working hours shall be 8am to 5pm on weekdays

# Development Work

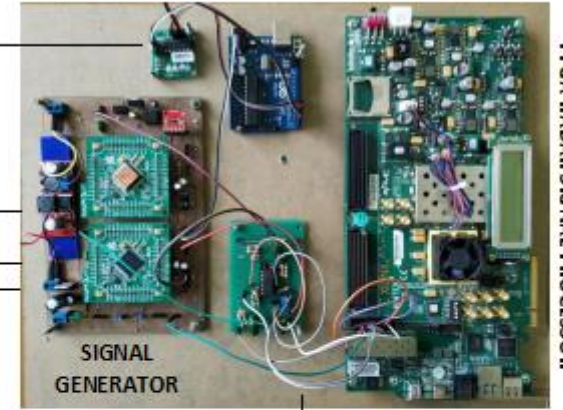
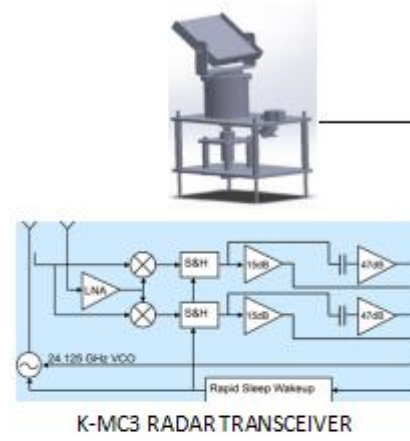
- The participants were provided
  - a training radar
  - FPGA SDK
  - radar display SDK
  - hardware parts
- The participants used the training radar as a substitute of the radar transceiver that is to be developed by another radar team to demonstrate the *signal processing functions* developed
- The *radar display capability* was demonstrated by the participants



# Deliverables



*Hard work, Teamwork  
Persistence, Technical Knowhow,  
Willingness to learn  
Training, Guidance  
Supervision*



DSSTRC  
to-be-developed  
Signal Processor

IP NETWORK

DSSTRC  
to-be-developed  
Radar Display



Initial Design Concept

Final Implementation

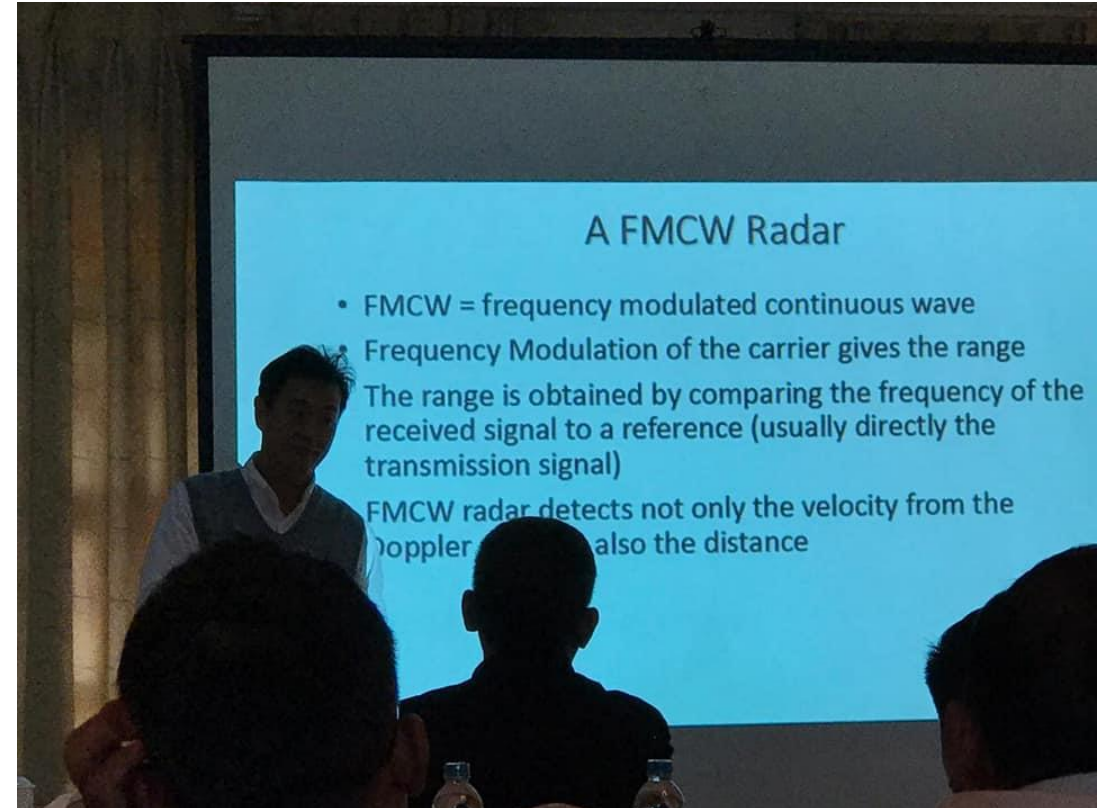
# Customized Courses

# Training and Courses

- Participants attended all the scheduled training diligently
- All the course contents are entirely understood
- Completed the course feedback form for each course
- Completed a Training Report for each course
- The training conducted
  - RF and Microwave Techniques in Radar Engineering
  - Radar Interfacing and Signal Processing Techniques
  - FPGA for Radar Signal Processing
  - Radar Display Development.

# Courses

- Courses
  - RF and Microwave Techniques in Radar Engineering
    - Singapore
    - Instructor: Lee KH (TBSS)



## A FMCW Radar

- FMCW = frequency modulated continuous wave
- Frequency Modulation of the carrier gives the range  
The range is obtained by comparing the frequency of the received signal to a reference (usually directly the transmission signal)
- FMCW radar detects not only the velocity from the Doppler effect, but also the distance



# Courses

- Courses
  - Radar Operations, Theory and Design (covering FMCW)
    - Singapore
    - Instructors: Andre (Sky Radar), Christian (Radar Tutorial), Lee KH (TBSS)
  - FPGA Programming
    - Myanmar
    - Instructor: James, Robert (Hong Kong)
  - Radar Interface and Display
    - Singapore
    - Instructor: Lee KH (TBSS)

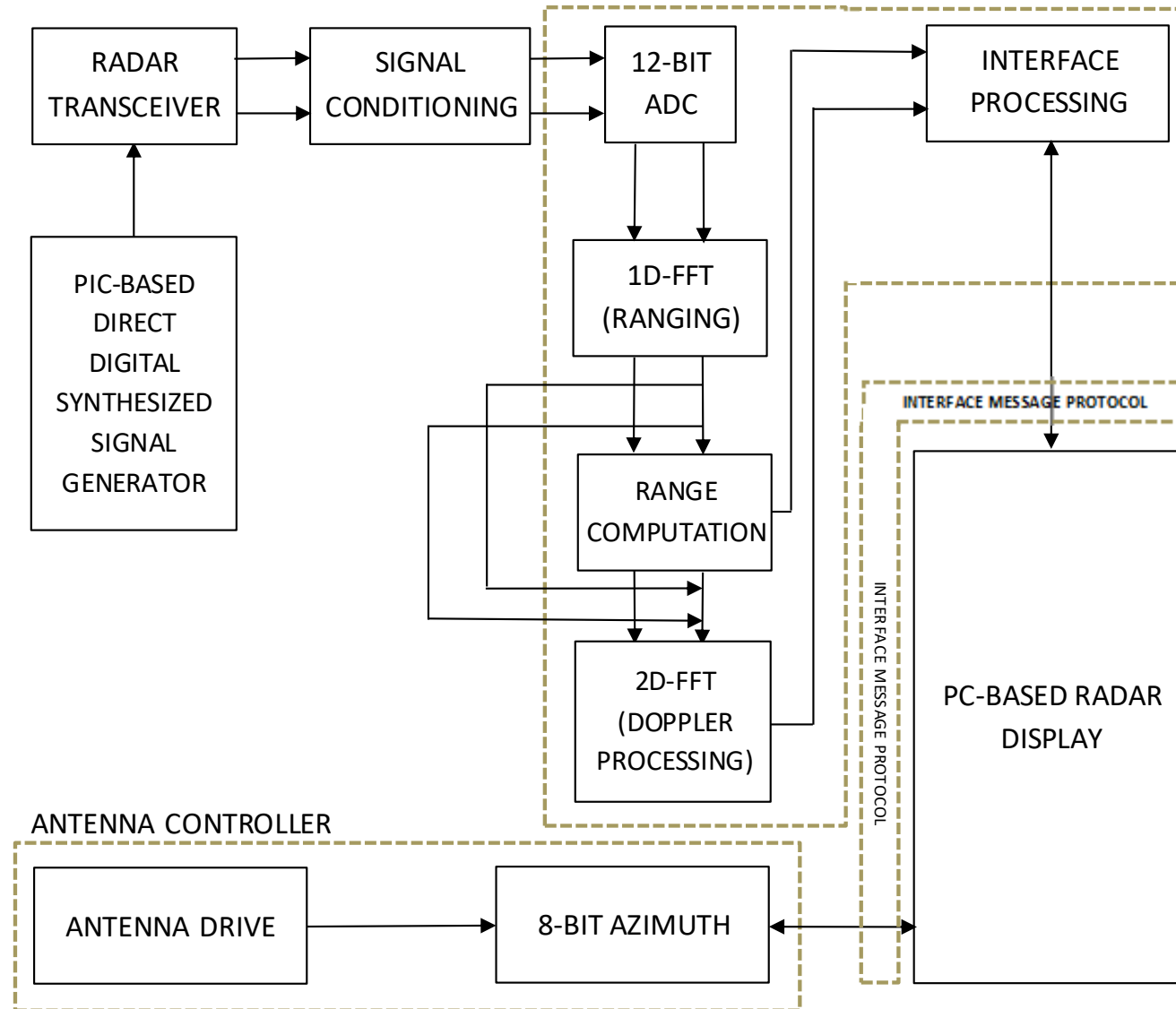




# Program Outcomes

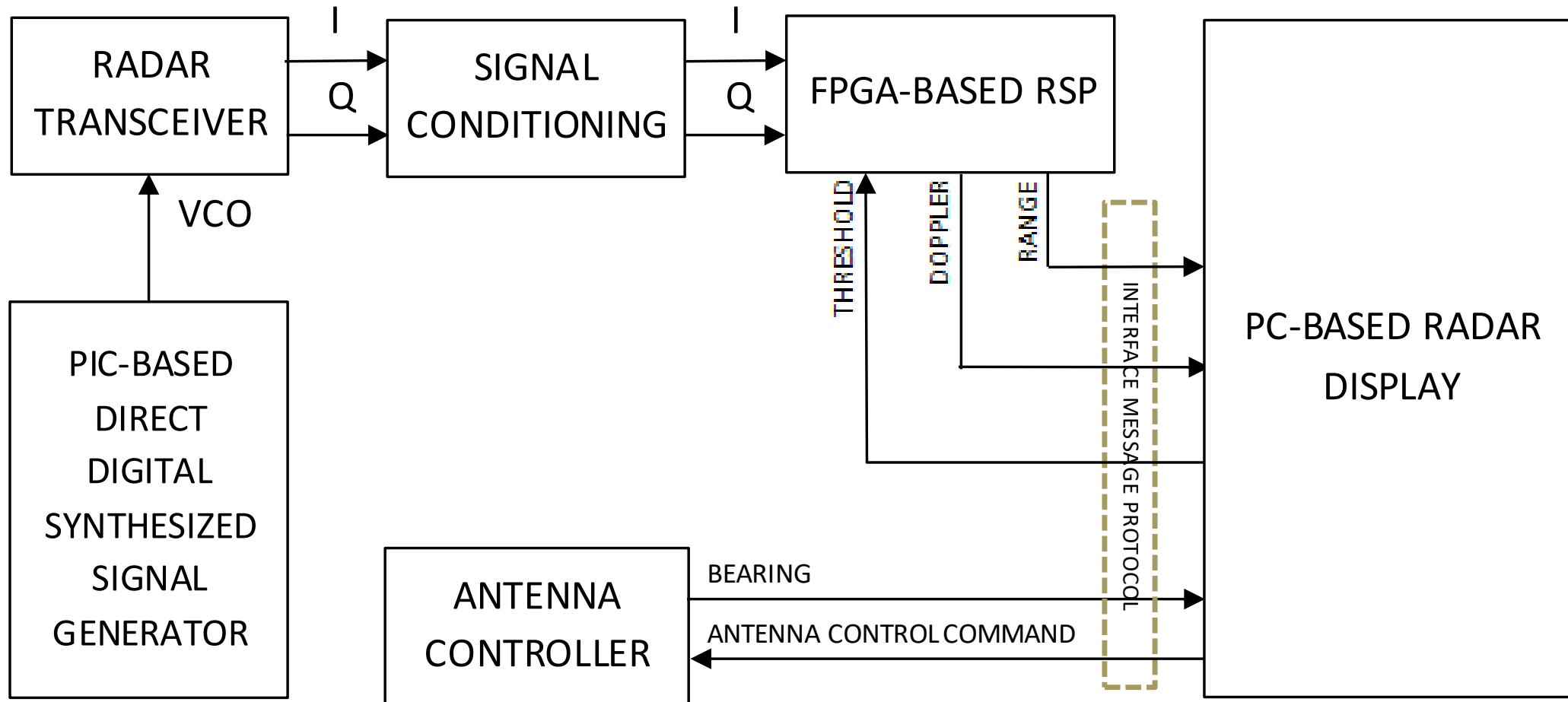
# Prototype

- Block Diagram:



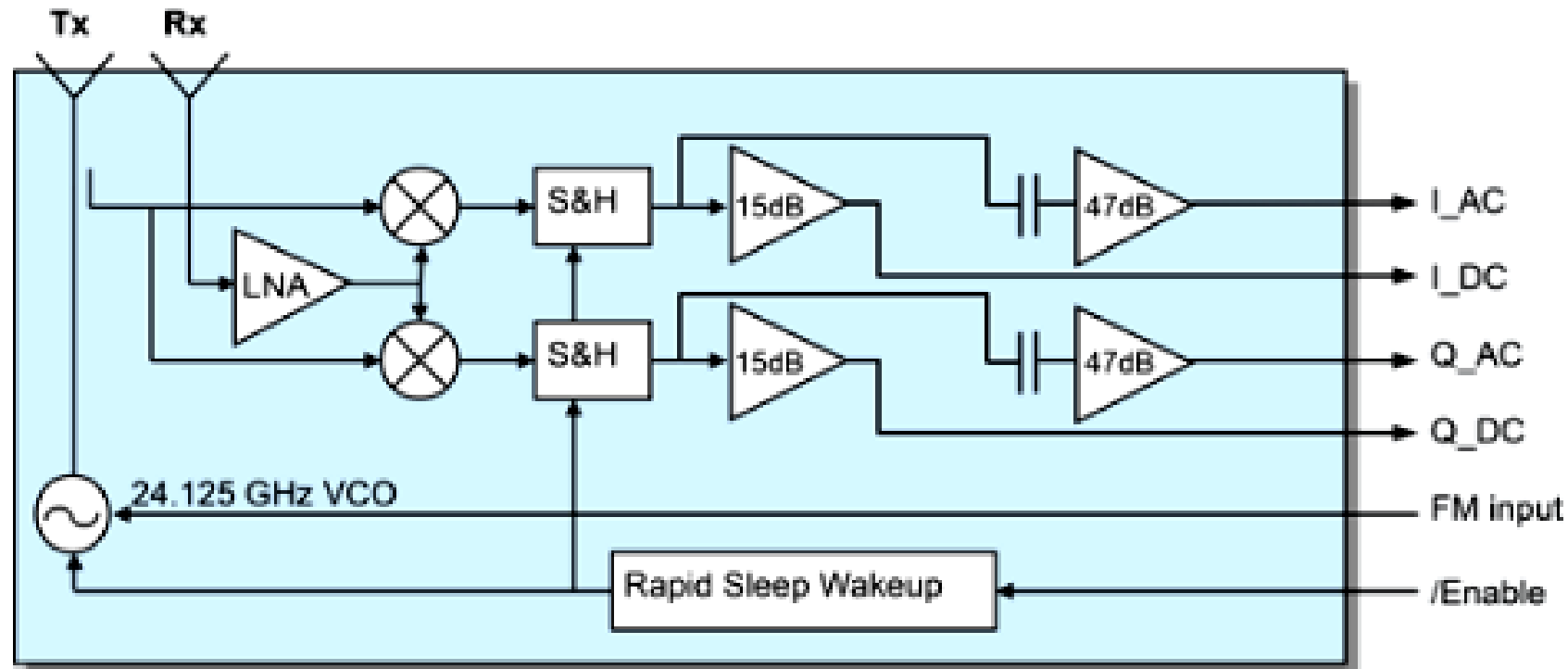
# Prototype

- Signal Flow Diagram:



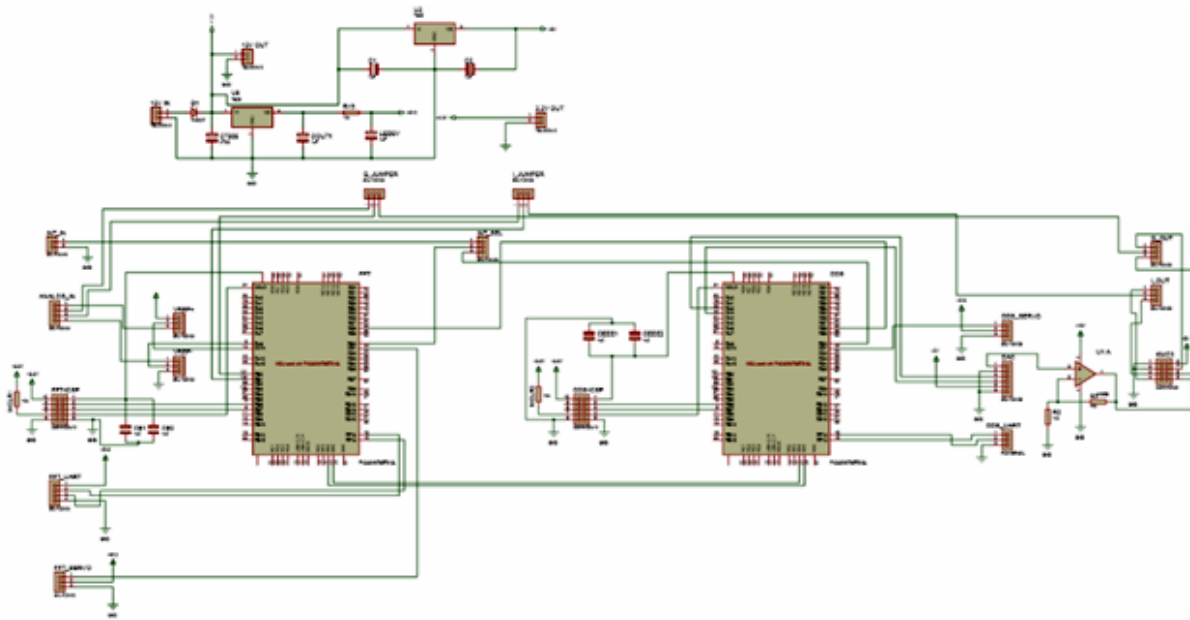
# Prototype

- Radar Transceiver:
  - The radar transceiver is the RFBeam K-MC3, it is a FMCW radar transmitting at 24 GHz that gives I and Q outputs
  - The transceiver takes in the FM input from an external source

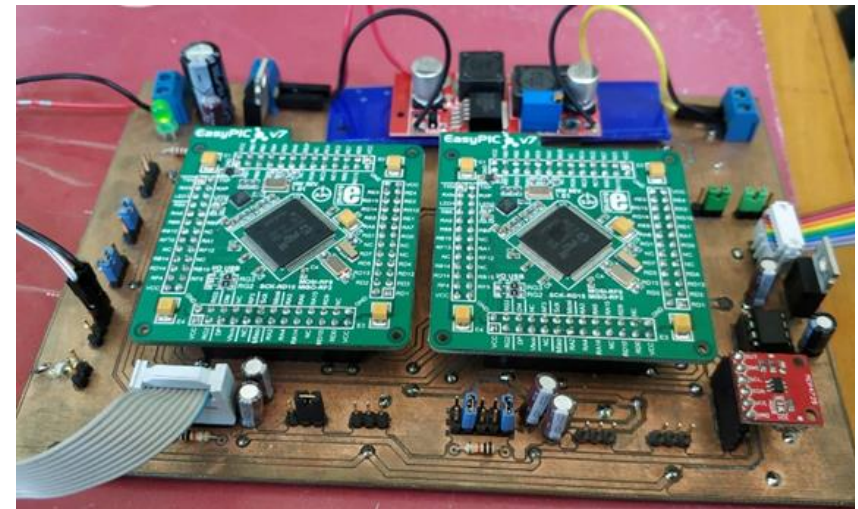


# Prototype

- Signal Generator:
  - The signal generator is implemented using PIC as a direct digital synthesizer, it drives the Radar Transceiver
  - It produces a 0 - 10 V, 4 ms, 250 Hz saw-tooth waveform (VCO) to modulate the carrier of 24 GHz



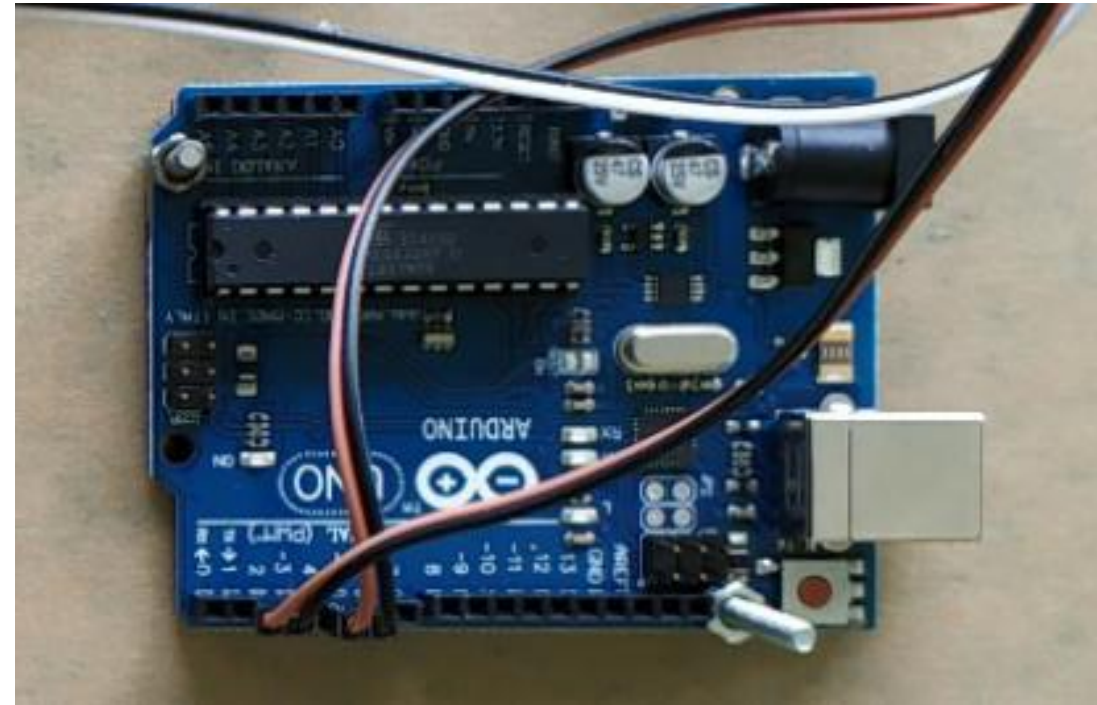
a. Schematic Diagram



b. Hardware

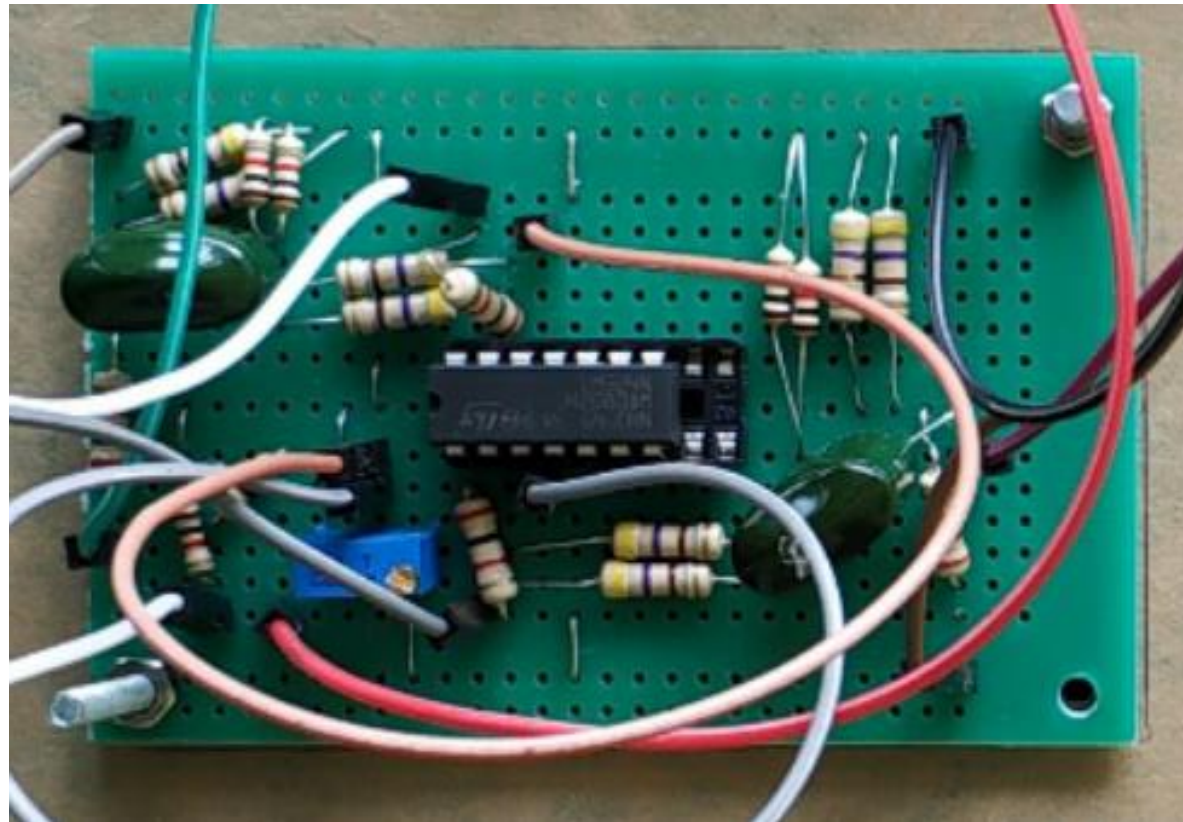
# Prototype

- Antenna Controller:
  - The antenna controller is implemented controls the pedestal
  - It provides sector scanning by giving the start and stop angles and gives the instantaneous antenna position to the PC-Based Radar Display Display
  - The antenna controller is using the Arduino Uno
  - The antenna position of the rotating antenna is obtained by mean of an encoder, the controller transmits the antenna bearing to the signal processor every 60 ms



# Prototype

- Signal Conditioning:
  - It filters and amplifies the I and Q signals given by the radar transceiver for further processing









# Prototype

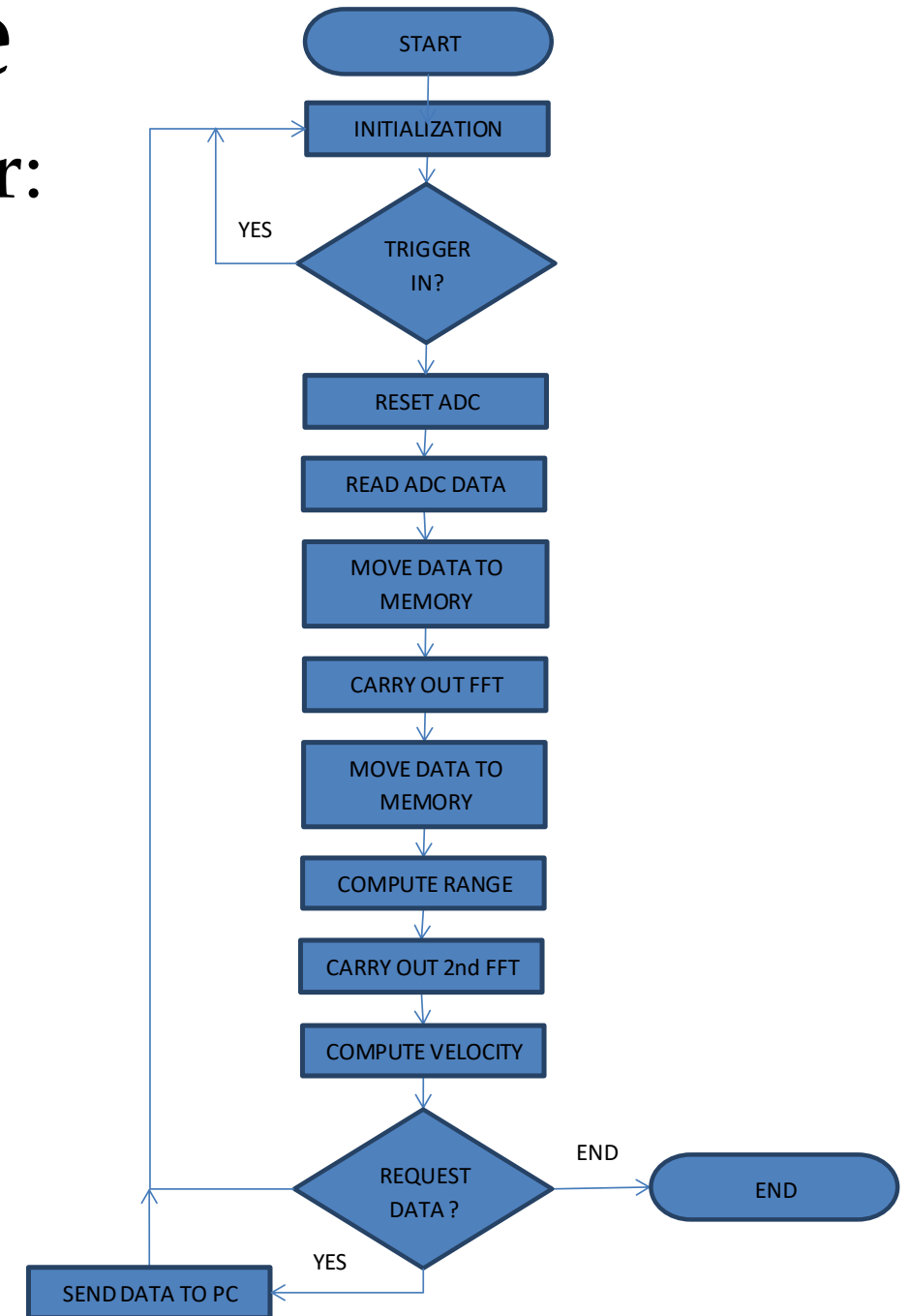
- FPGA-Based Radar Signal Processor:
  - The sampling of radar I and Q signals at 1 Msps sampling rate is performed using the on-board ADC converter
  - After processing the radar signal, the processor will forward the range and Doppler data to the Radar Display,
  - Radar Display is able to set the threshold

# Prototype

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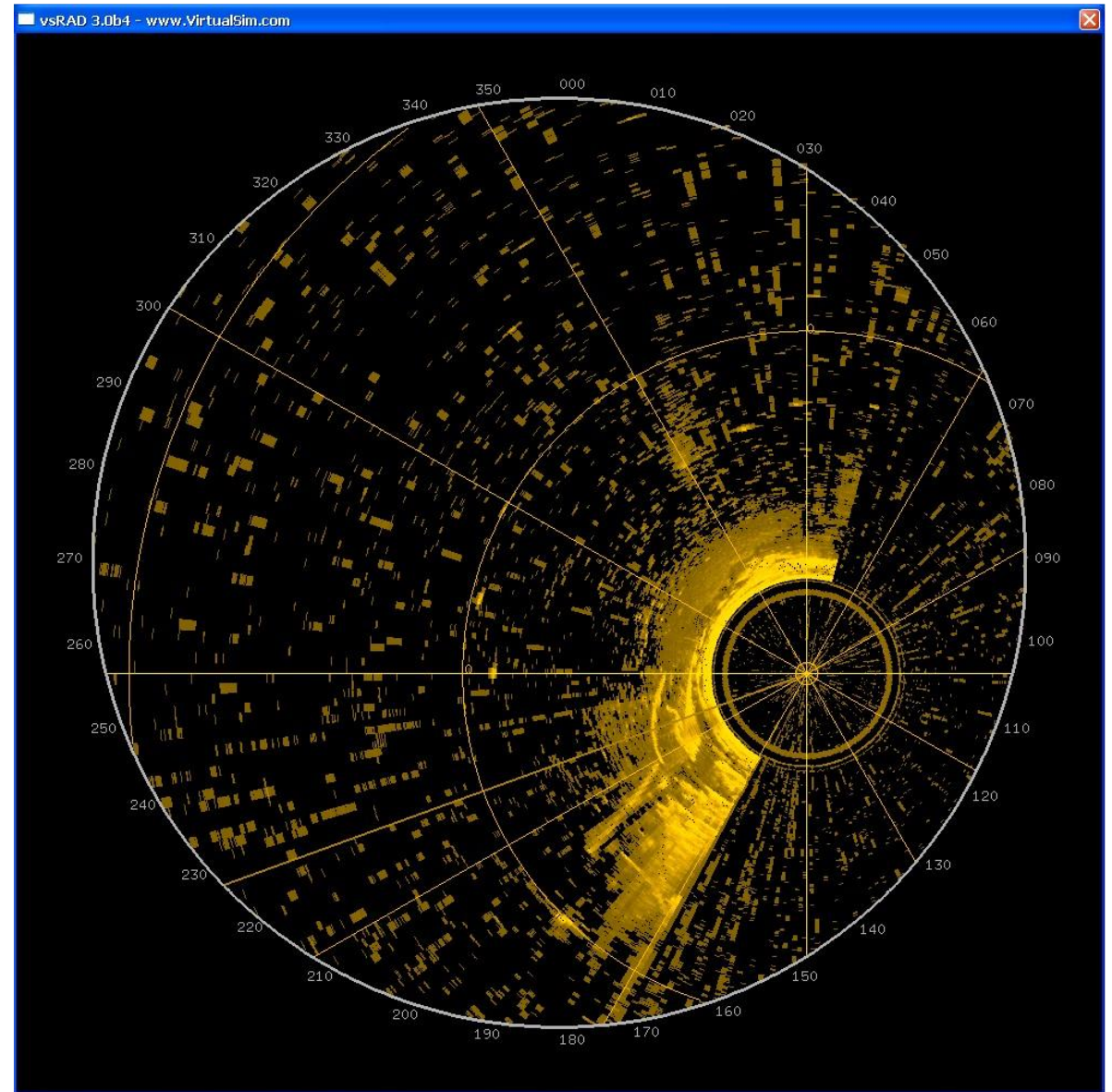
# Prototype

- FPGA-Based Radar Signal Processor:
  - The Flow Diagram



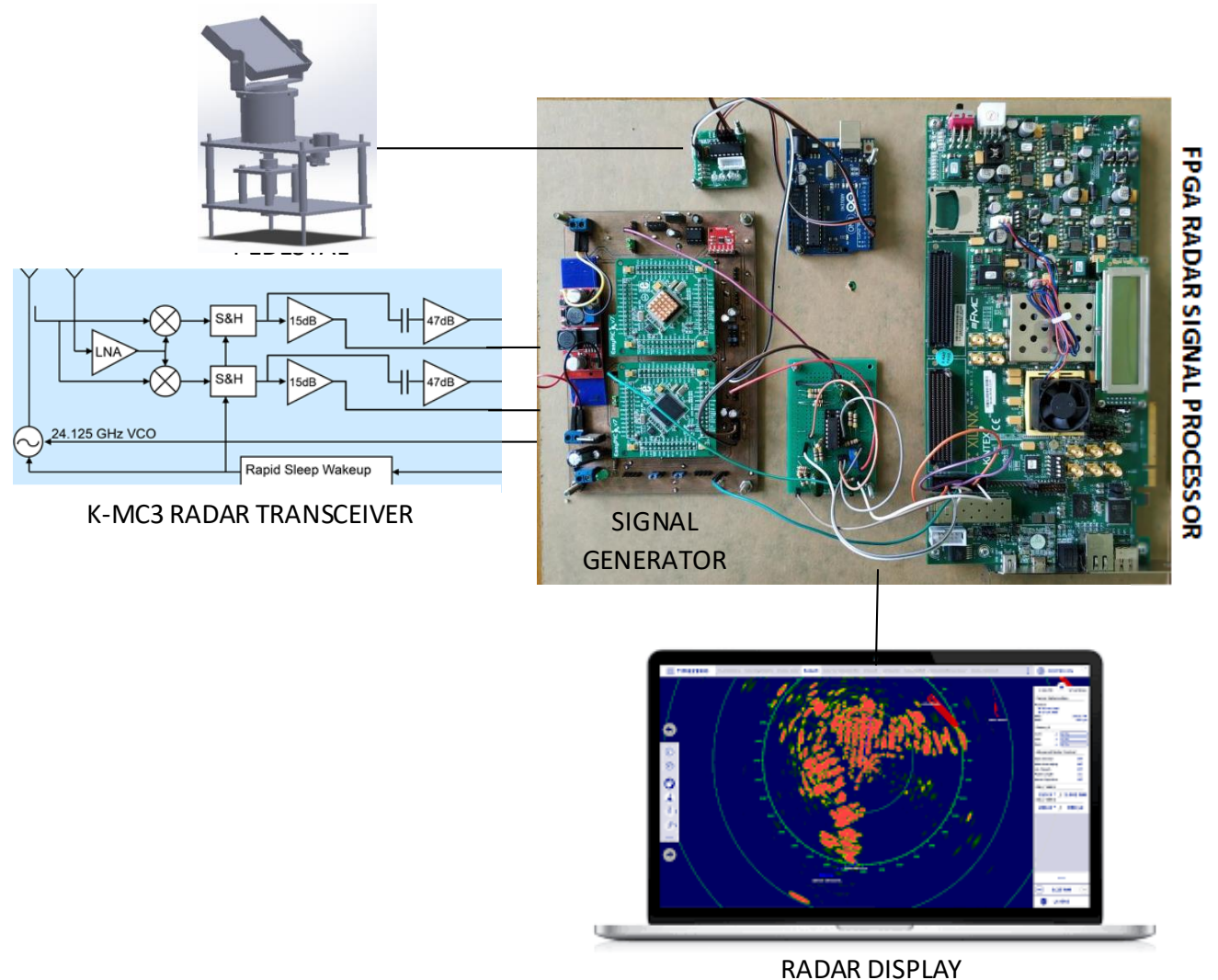
# Prototype

- Radar Display:
  - Runs on a laptop computer
  - The radar display software receives the radar signal processor outputs in terms of Range, Doppler and Azimuth in an agreed interface protocol by the Signal Processing and Display team members.



# Prototype

- Hardware Connection:
  - In this program, except for the radar transceiver and computer, most of the hardware are constructed and built by the program team.



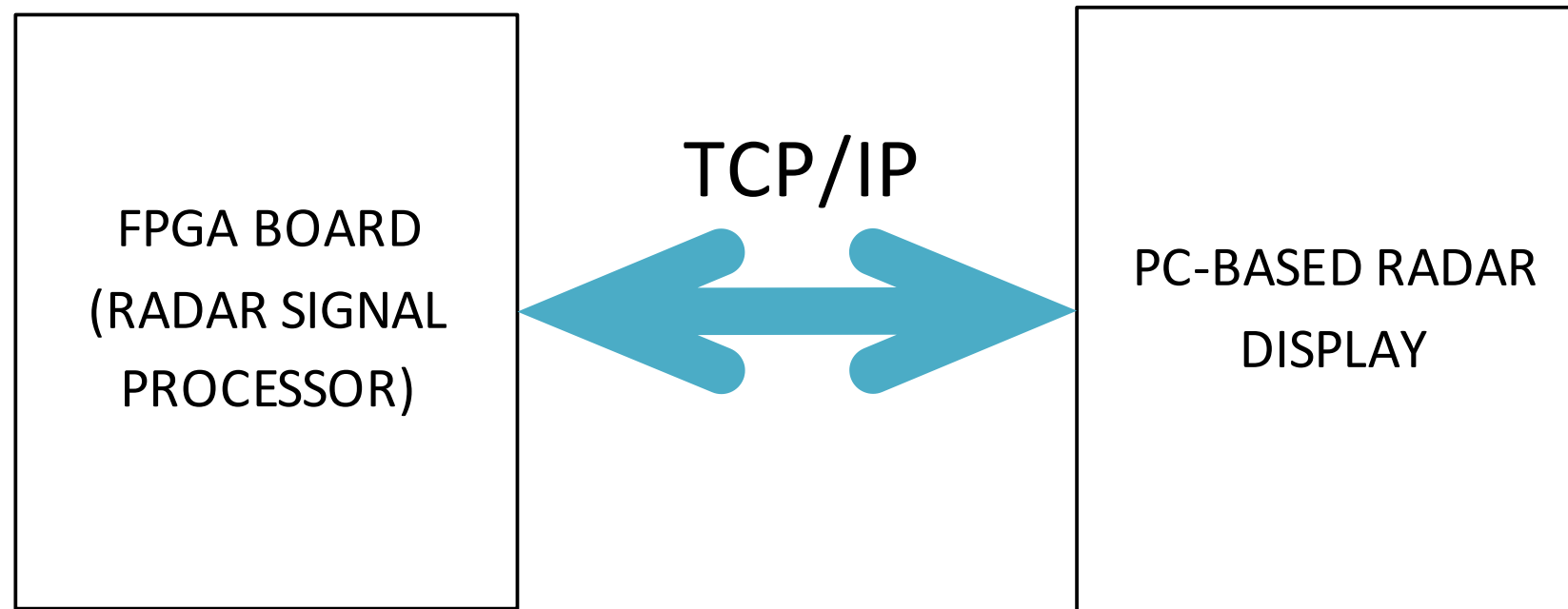
# Prototype

- Hardware Connection:
  - The radar display and control are implemented using a PC-Based Radar Display Development Kit
  - The kit is able to take in standard radar signals such as video, sync and antenna position
  - It is also capable of control the antenna controller and the threshold of the signal processing
  - In this project the radar data and control commands are transmitted and received by the radar signal processing and radar display via an agreed interface message protocol



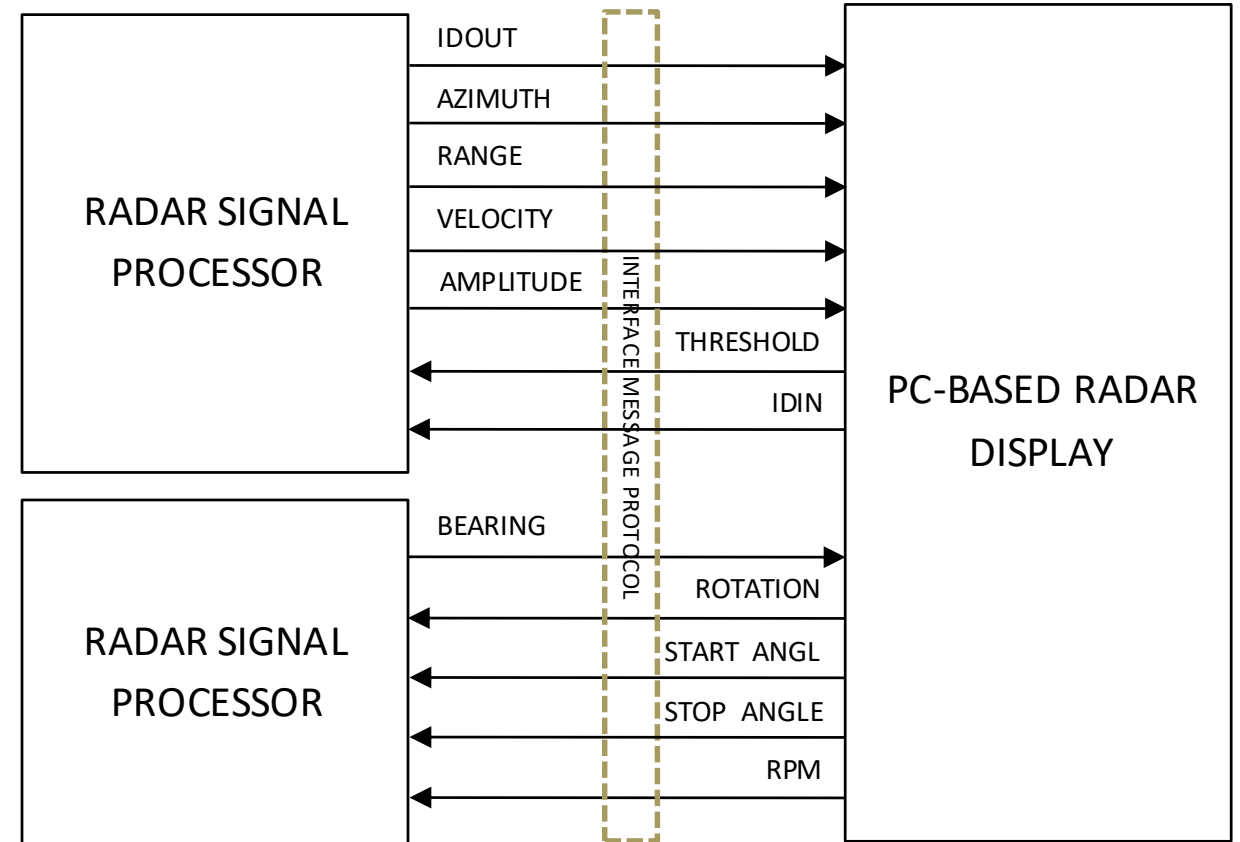
# Prototype

- Interface Message Protocol:
  - The interface between the radar signal processor, antenna controller and radar display is implemented in TCP/IP format via the Ethernet port on the Radar Signal Processor Board and the Radar Display Computer



# Prototype

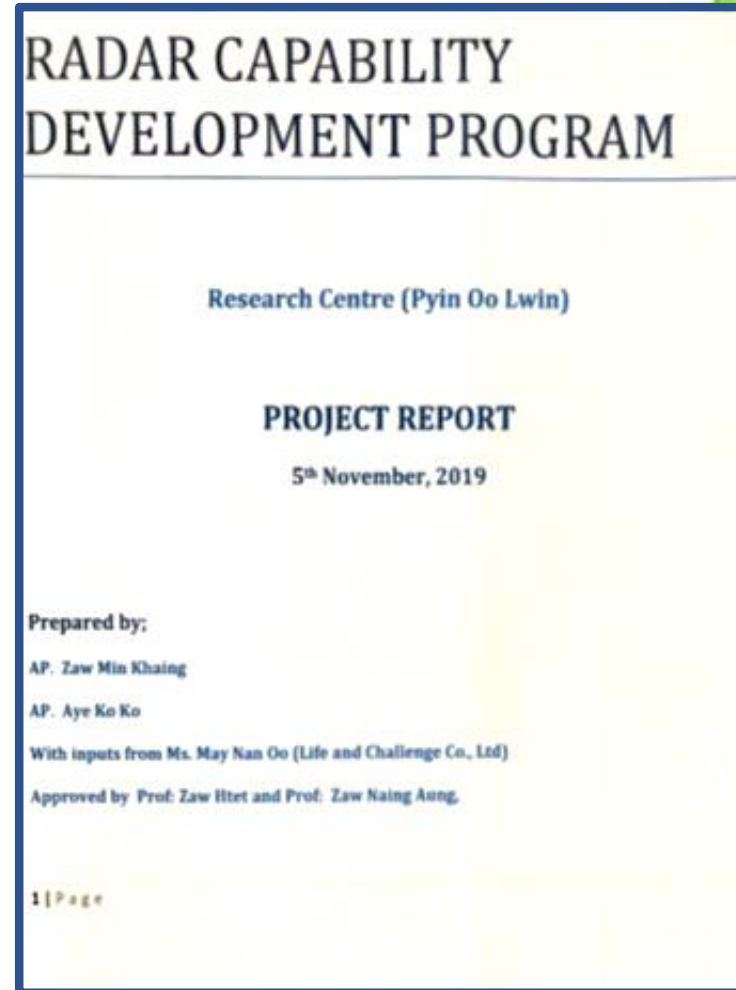
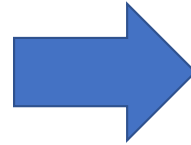
- Interface Message Protocol:
  - The data exchange in TCP/IP format via the Ethernet port contains the fields that are used for display and control purposes
  - There are 12 fields in the message protocol
  - Each field is 4 byte long giving a total of 48 bytes per transmission.



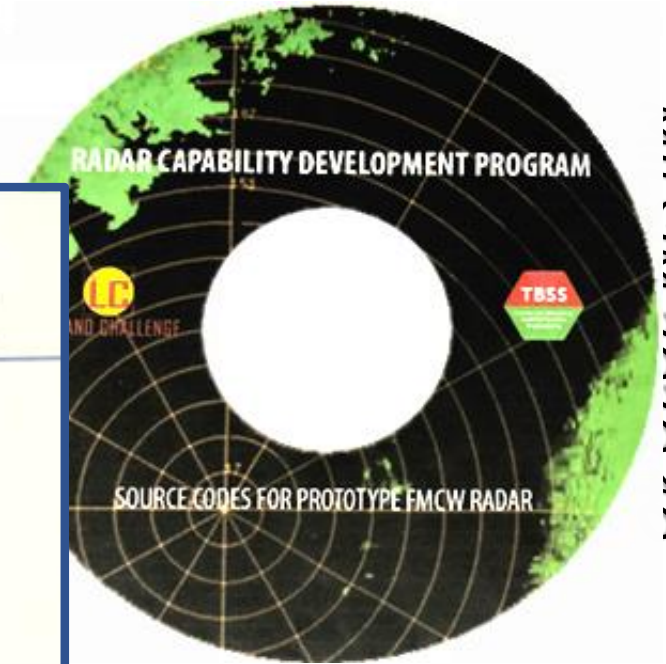
# Project Documents



**Interim Reports**



**Final Submitted Report  
(Printed)**



**Final Code  
Version  
(CD)**

# A More Competence Team

- Team work
  - the team had shown great cohesion to ensure the project is completed successfully
- Leadership
  - AP LTC Dr Zaw had demonstrated great leadership in the GUI team management
  - AP LTC Dr Ayekoko demonstrated great leadership in the signal processing team management
- Keen to learn
  - The team members have demonstrated that they were very keen to learn during the training courses and project development

# Prototype

- Willingness to help
  - the faulty FMCW unit was repaired largely due to the help given by the team to provide remote access and practical rectification and verification
- Ownship
  - The team took a passionate approach to ensure the project is successful
  - The entire team were presented in all the meetings
- Capability
  - The team is now ready to built their own radar signal processor and display

# Recommendations and Conclusion



# Recommendations

- Radar RF design including transmitter, receiver and antenna
  - Use of appropriate Electronic Design Automation tools
  - Fabrication of radar transceiver and antenna
- Radar Tracking
  - Single target tracking
  - Track-While-Scan
  - plot extraction, plot-to-track association and tracking algorithm
- User Interface Tool
  - More comprehensive tool can be used to facilitate the user interface

# Summary

- The teams have successfully developed a radar signal processor on FPGA that receives radar signal from a supplied transceiver
- The teams have successfully interfaced the radar signal processor and a radar display and control user interfaced
- The team members have acquired adequate knowledge and skill from the capability development program
- A great relationship between the Client and TBSS has been built

**Thank You  
Terima Kasih**