Phased Array Receiver Prototype for TNRT

By

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OUTLINE

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2. Scope
3. Concept design
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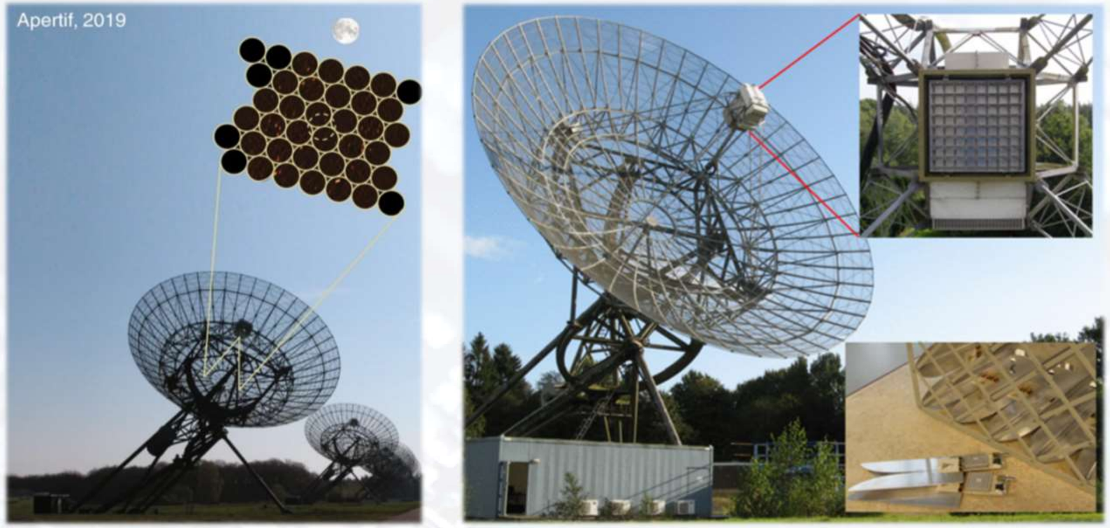
1. Project Introduction & Objectives



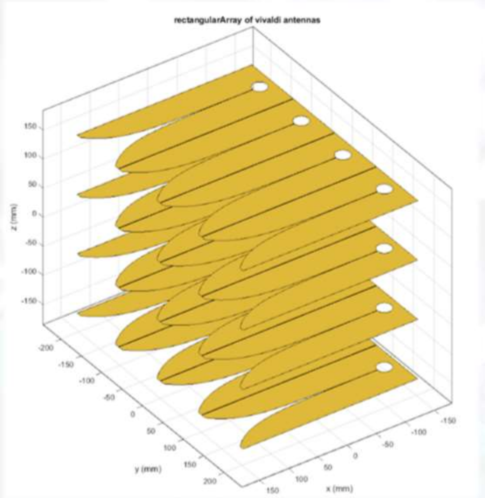
Source: APERTIF PAF, Westerbork Synthesis Radio Telescope, ASTRON, Netherlands

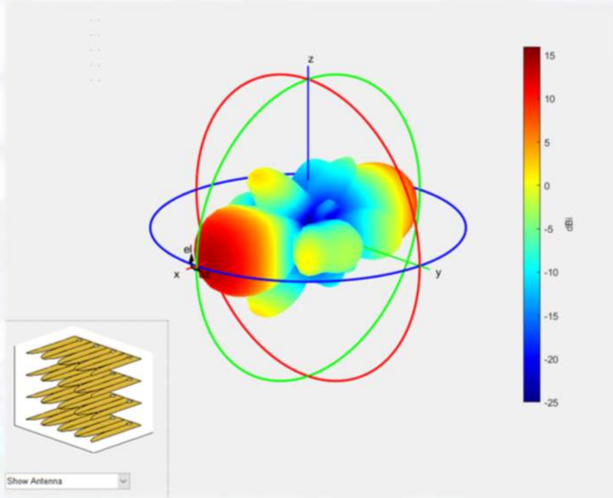

TNRT, Chiang mai, Thailand

- This project is proposed to do the **"Phased array receiver protype"** for ***TNRT***.
- **Study and research** on **designed know-how** preparing the development for TNRT.
- Plan for 3 years, **FY2022 – 2024:**

  Concept design → Implement to system → Observe (test)
- **Increasing Field of View of TNRT** by using beam steering technique for Sky survey, on next phase of TNRT's receiver development.

2. Scope

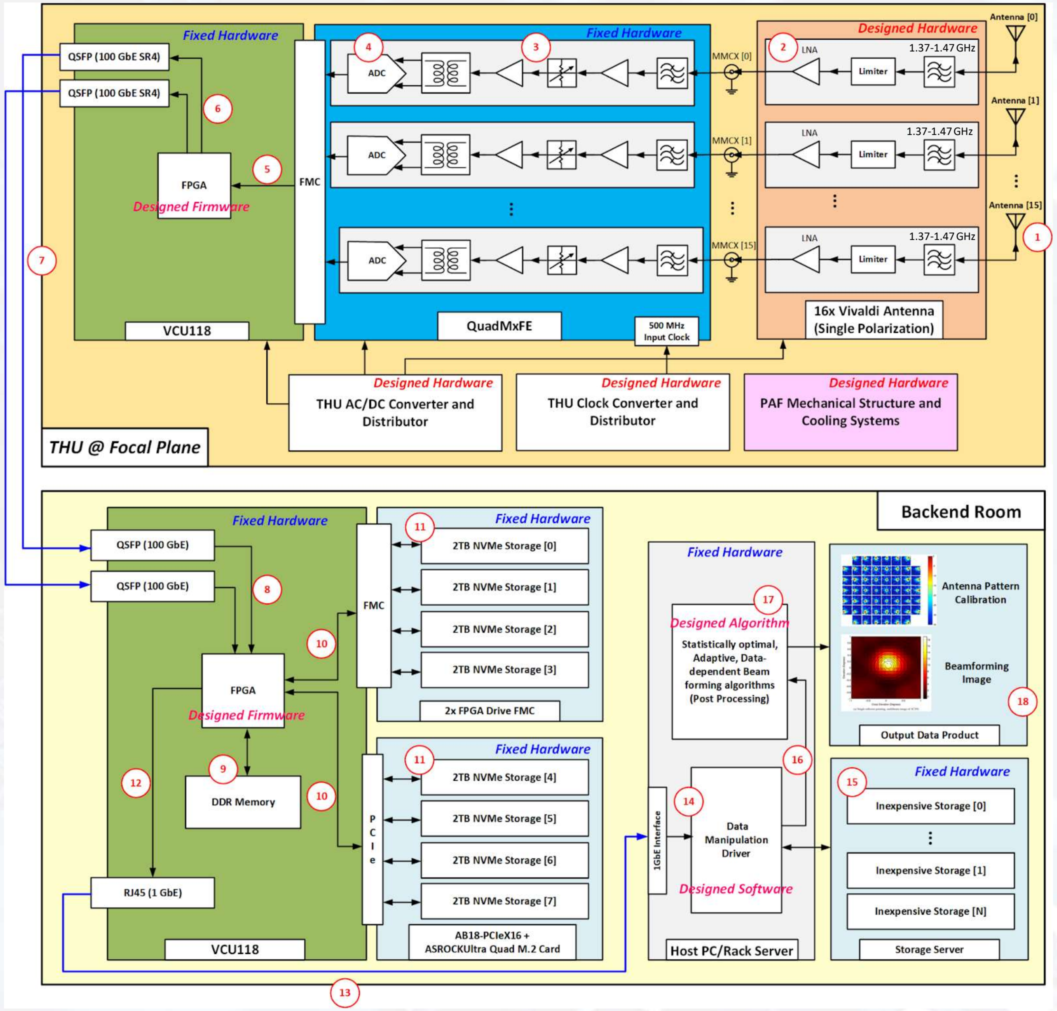


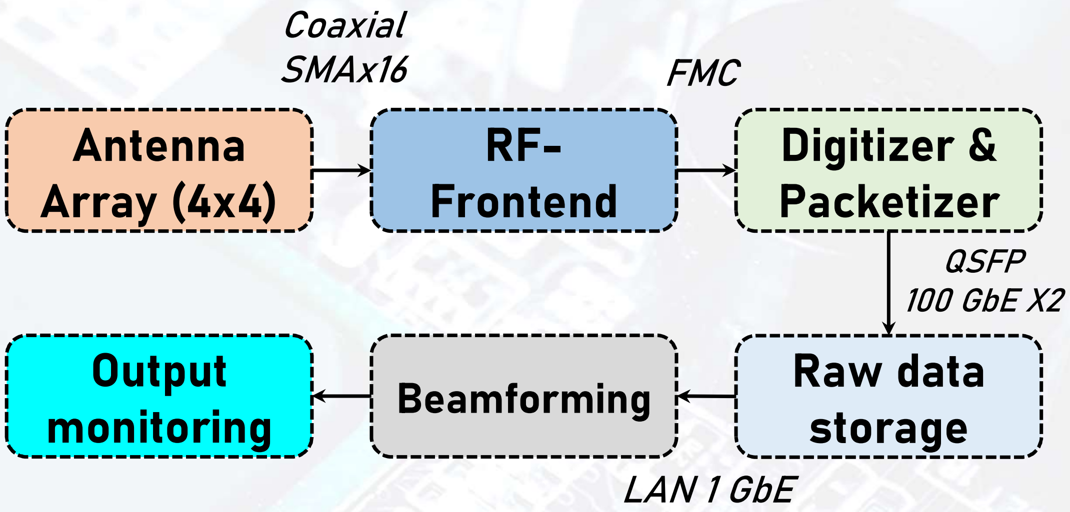


Source: https://svs.gsfc.nasa.gov/4657

- Create for **Sun tracking application** by Hydrogen line (HL)
- Center frequency at **1.42 GHz,** Neutral Hydrogen's frequency
- Phased array antenna size = **4 x 4 = 16 elements**, with **single polarization**
- Digital Beamforming
- Output data format: **Data cube (time/frequency/magnitude)**

3. Concept design

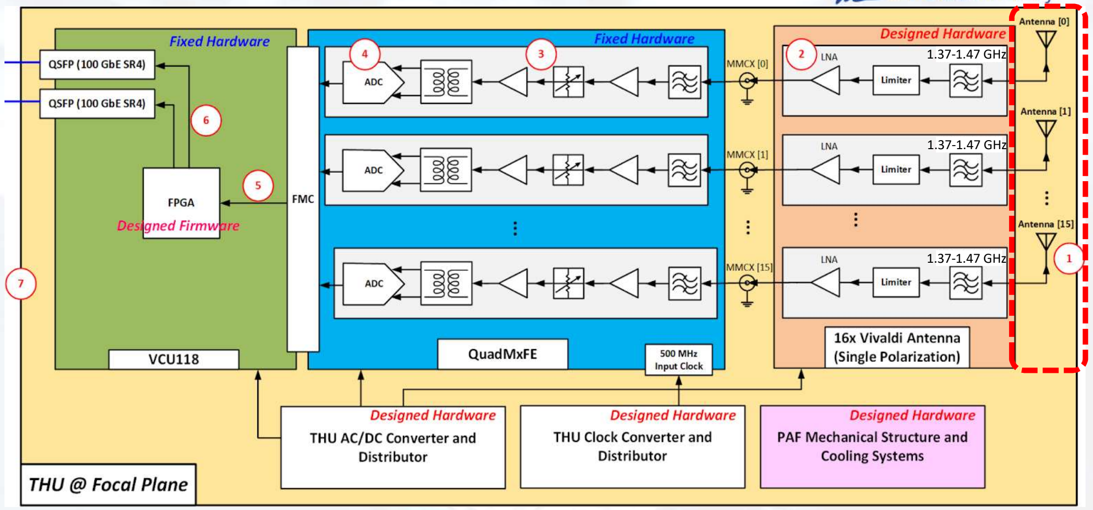


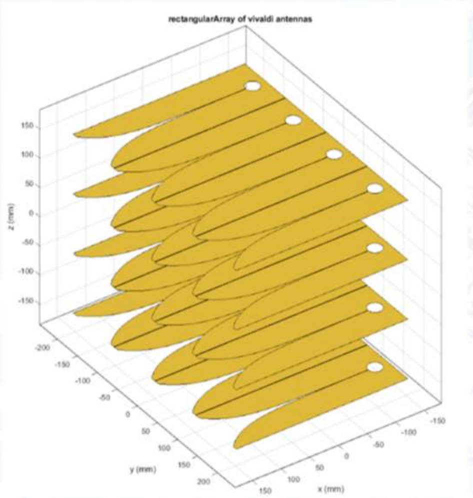


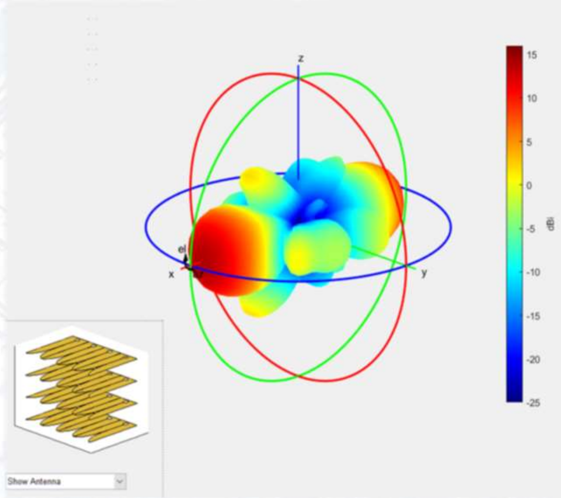
3. Concept design

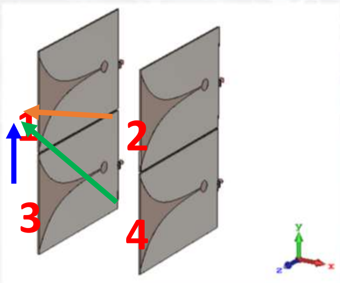
i. Antenna Array

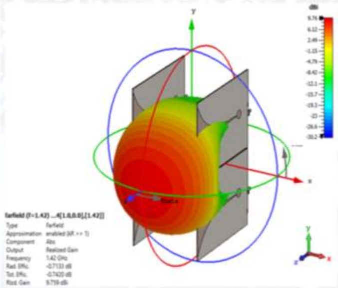
- Center frequency **1.42 GHz**
- Operating frequency **1.37-1.47 GHz** (100 MHz of bandwidth)
- Size **4 x 4** , total **16 elements** with **single polarization**
- Each element is **Vivaldi** antenna
- Convert **RF signal → Electric currents** and feed to RF chain for further process
- Each antenna receives **different phase** of RF signal with same offset and gain

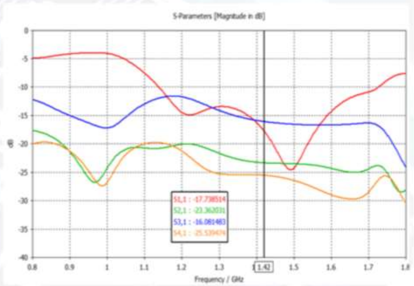




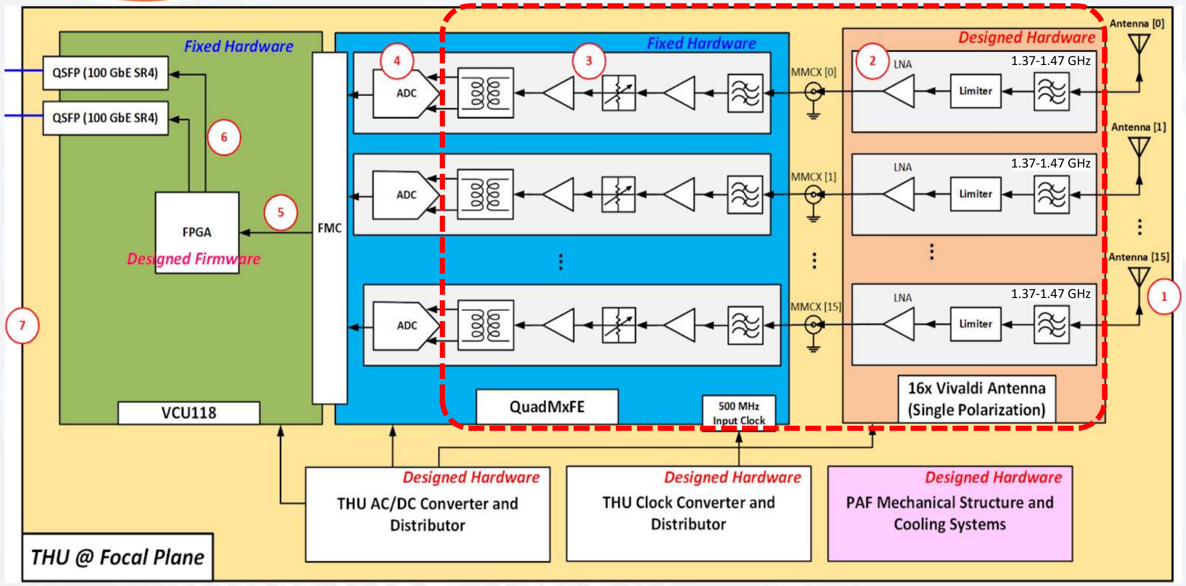






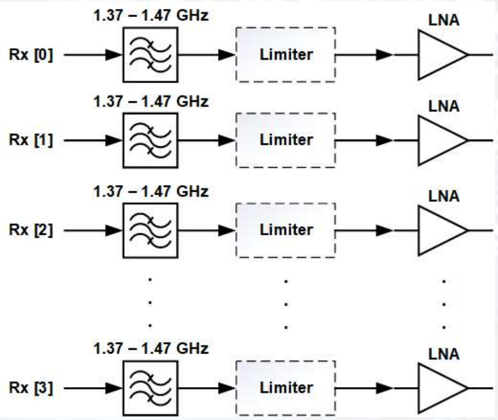


3. Concept design

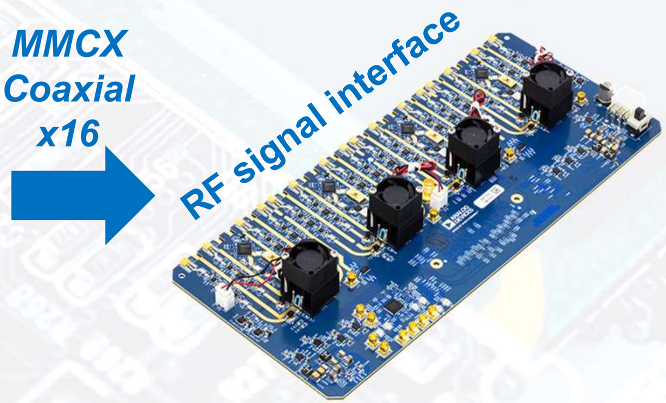


ii. RF-Frontend

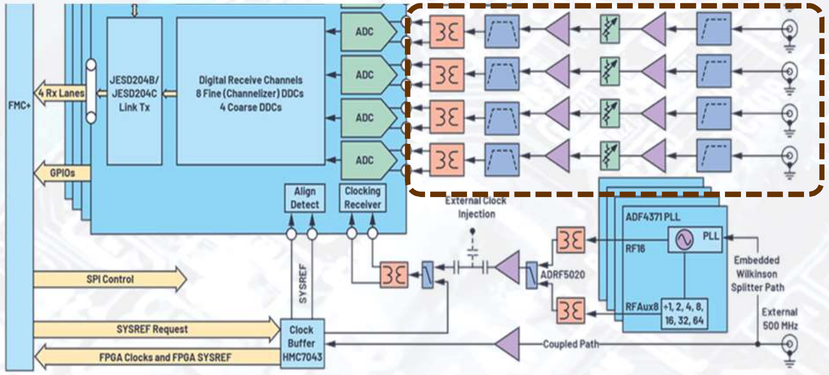
- **Allow passband signal**, **improve quality of signal**, such as SNR, signal gain, power level, etc.
- **Composes with 2 stages**: Designed RF circuit, Digitizer module (ADI's Quad-MxFE)
- Main components:
  - Bandpass filter
  - Limiter
  - Low Noise Amplifier
  - Digital Step Attenuator



Designed RF circuit



Quad-MxFE

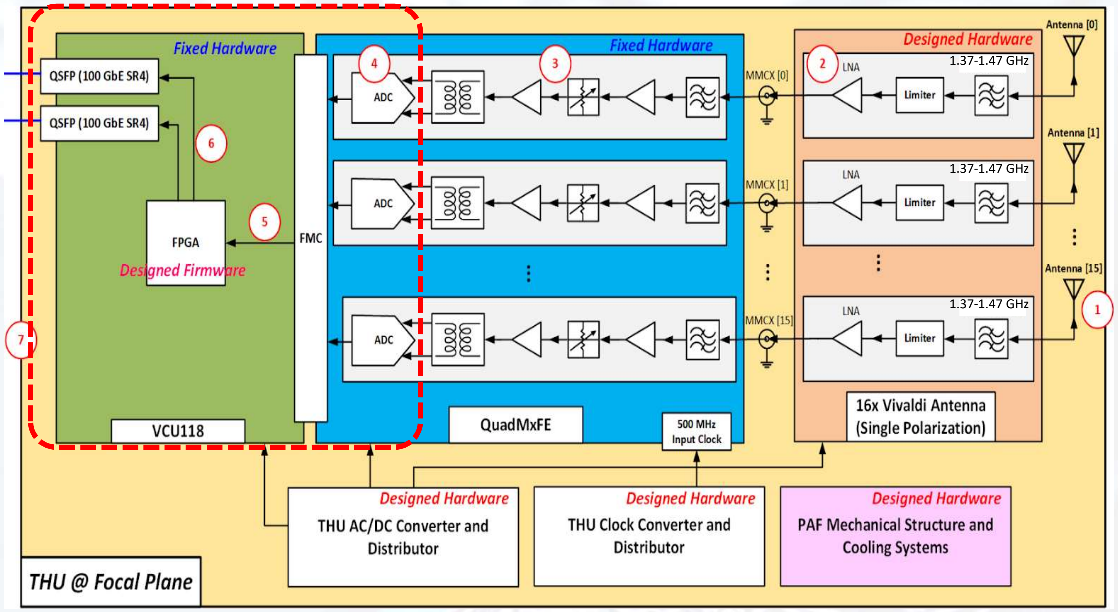


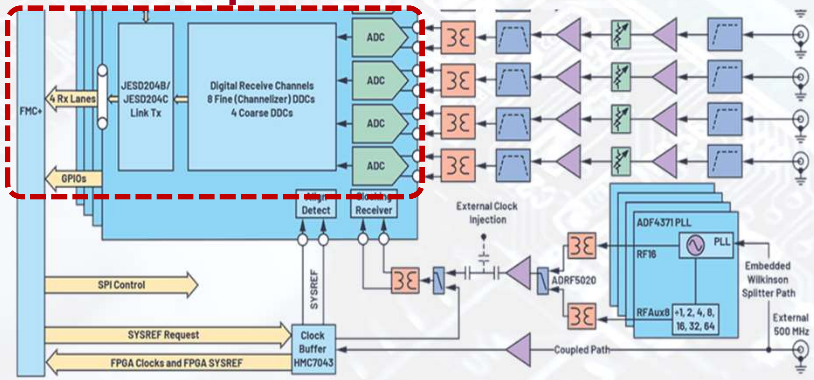
Quad-MxFE's RF chain

3. Concept design

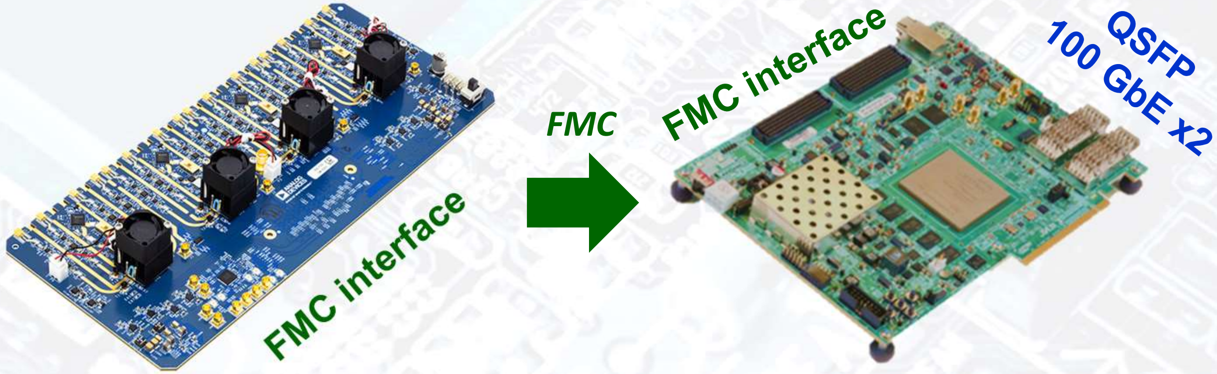
iii. Digitizer & Packetizer

- **Digitizer** (Quad-MxFE):
  - **ADC**: sampling rate 4 GSPS, 12-bit x 16 channels
  - **Digital Down Converter (DDCs):** convert RF signal → baseband I/Q pair (sampling > 100 MHz x 32 channels)
- **Packetizer** (FPGA VCU118):
  - Add header & pack the I/Q data as payload of **UDP protocol**
  - Sent out **UDP packets** via **2x 100 GbE QSFP port**





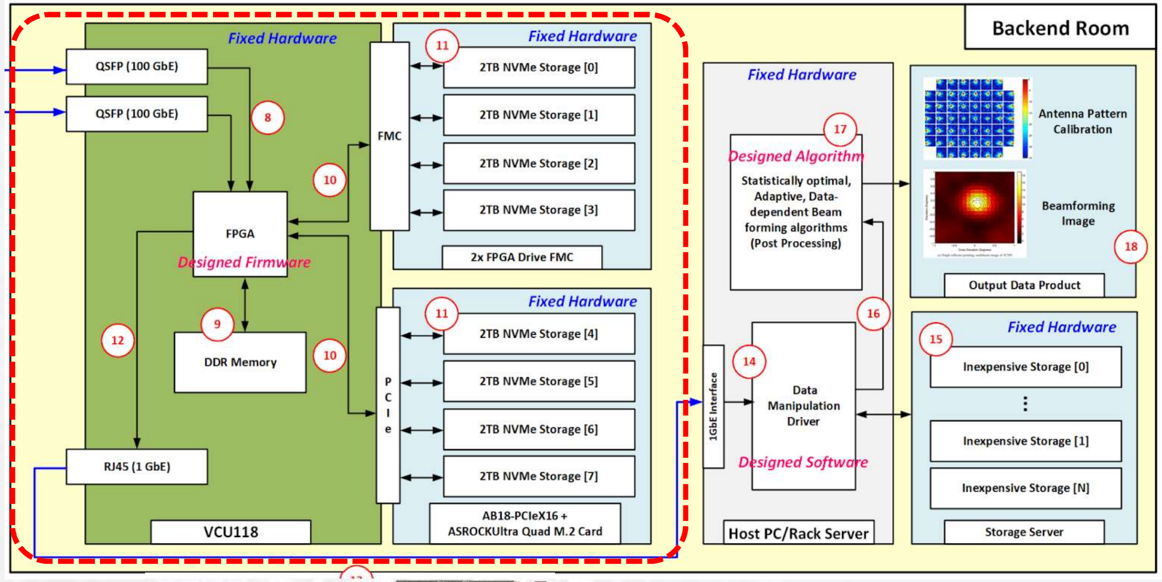
Quad-MxFE's ADC & DDC



Quad-MxFE

FPGA VCU118 [0]

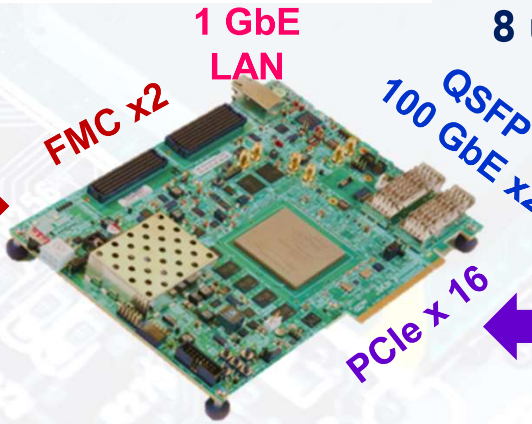
3. Concept design



iv. Raw data storage

- Composes with **3 parts**: FPGA Data manager, FMC Dual NVMe M.2 SSD, PCIe Quad NVMe M.2 SSD
- **Record UDP packet** data from Packetizer via 2 x 100 GbE QSFP
- Another **FPGA VCU118** will be programmed to manage data (Write & Read) to/from memory storage
- On each 2 parts of memory storage, it includes **8 units x 2 TB NVMe M.2 SSD**
  - **Data query from NVMe storages** to the Beamforming processing unit via 1 GbE LAN over TCP/IP protocol.

Dual NVMe M.2 SSD x2



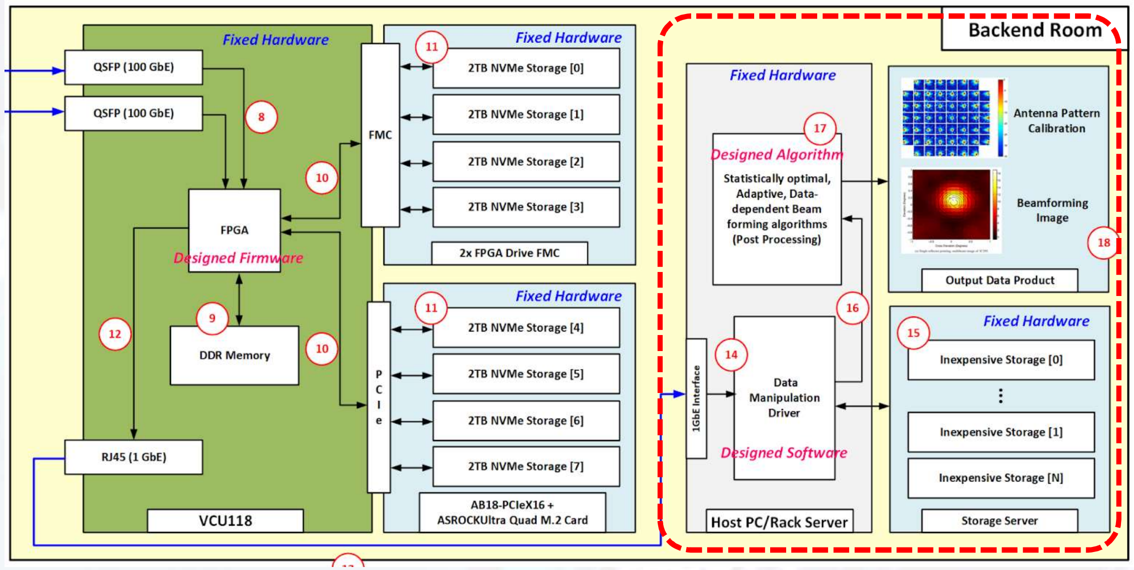
FPGA VCU118 [1]

Quad NVMe M.2 SSD

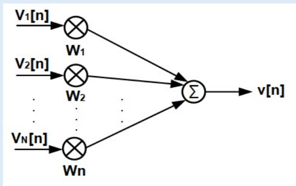
3. Concept design

v. Beamforming & Output monitoring

- **Offline processing** in software
- **Request data query** from **FPGA data manager** via **1 GbE LAN**
- Digitized data will be **backed up** on OS in hard-disk RAID **storage server** for **data protection**.
- For this process, **software design on program**, e.g. python, MATLAB, will be designed to get data for **Digital Beamforming algorithm** and **monitoring**.
- Sub-band beamforming with **weighting in frequency domain** for wideband beamforming
- **Output products:**
  - **Beamforming images**: spectral result to spectrogram
  - **Antenna pattern synthesis**

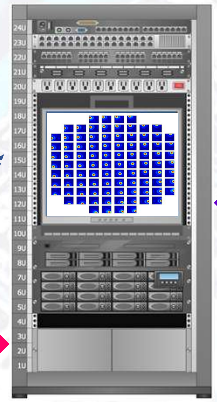


Beamforming program



From Data manager

RJ45 LAN 1 GbE



Processing unit (PC)

LAN interface

Storage server

4. Conclusion

- **Activity list of FY2022:**
  - ☑ New RF antenna engineer: Dr. Nattapong Duangrit
  - ☑ Concept design for prototype development
  - ☑ Purchase all required equipment and materials for next year hand-on plan
  - ☑ Start on Antenna design; simulation, fabrication, experiment plan
- **Plan for FY2023:**
  - ❑ Recruit new software engineer for Beamforming & Output monitoring development
  - ❑ Implement concept design -> real prototype in laboratory scale
- **Plan for FY2024:**
  - ❑ Apply real prototype in laboratory scale to OTA test