ET4169- Microwaves, Radar and Remote Sensing

Automotive Radar Lab

Faruk Uysal

Microwave Sensing, Signals and Systems (MS3) Group, TU Delft

Learning Objectives

- Observe radar signatures
- Apply range-Doppler processing
- Apply Angle of Arrival (AoA)
- Apply time frequency analysis

Lab Assignments

- Part-I :
  - apply and demonstrate the methods for angle of arrival estimation on different data
- Part-II :
  - micro-Doppler signature of humans as observed by an automotive radar.

Equipment

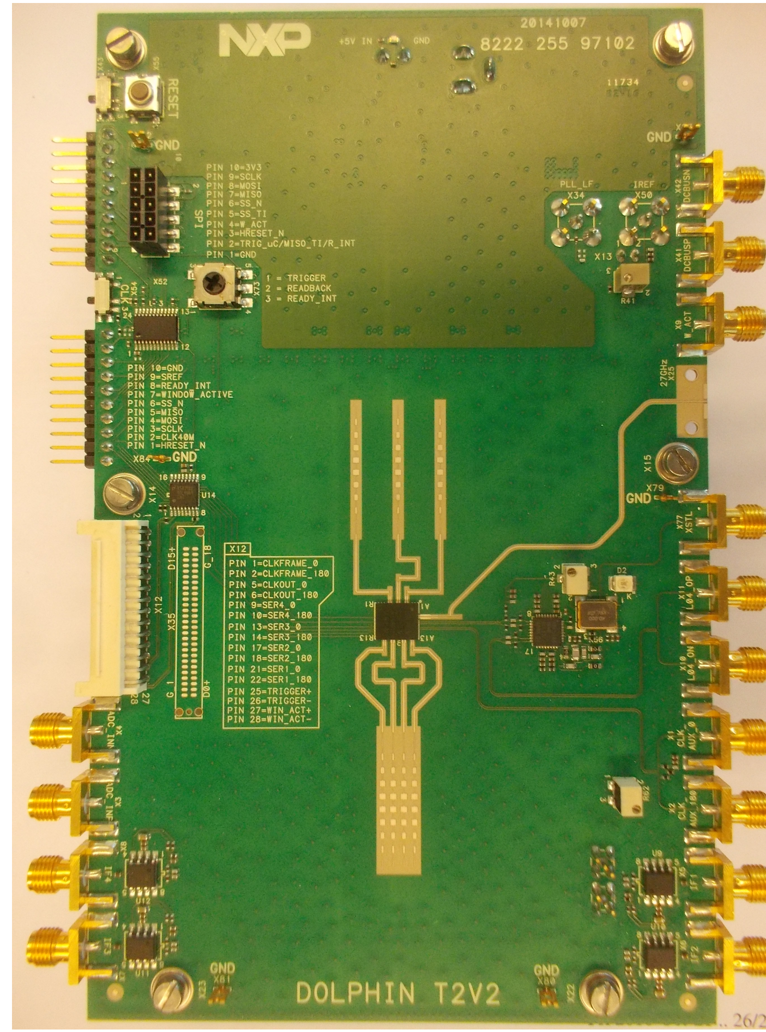
Possible Applications

Front-Side car:

- Autonomous Emergency Braking (AEB)
- Adaptive Cruise Control (ACC**)**
- Narrow Path Assist
- Lateral Collision Avoidance
- Side Pre-Crash
- Traffic Jam Assist

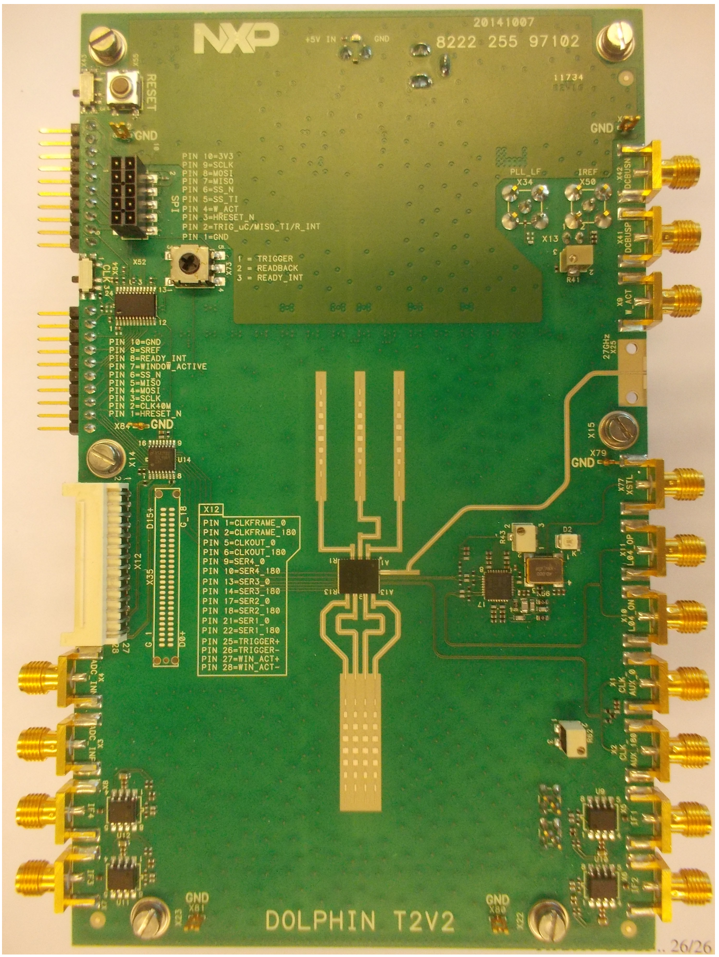
Rear-Side car:

- Lane Change Assist (LCA)
- Blind Spot Detection (BSD)
- Rear Cross Traffic Alert (RCTA)
- Rear Pre Crash
- Parking Assist (PA)

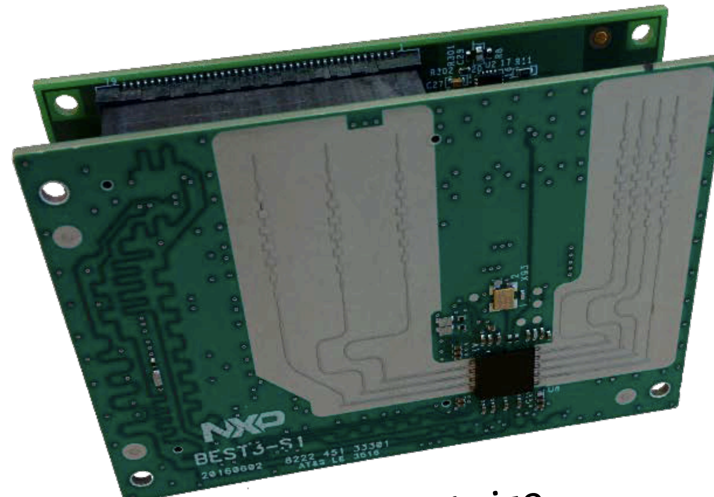


Operational frequency range 76-81 GHz

Evaluation Beard

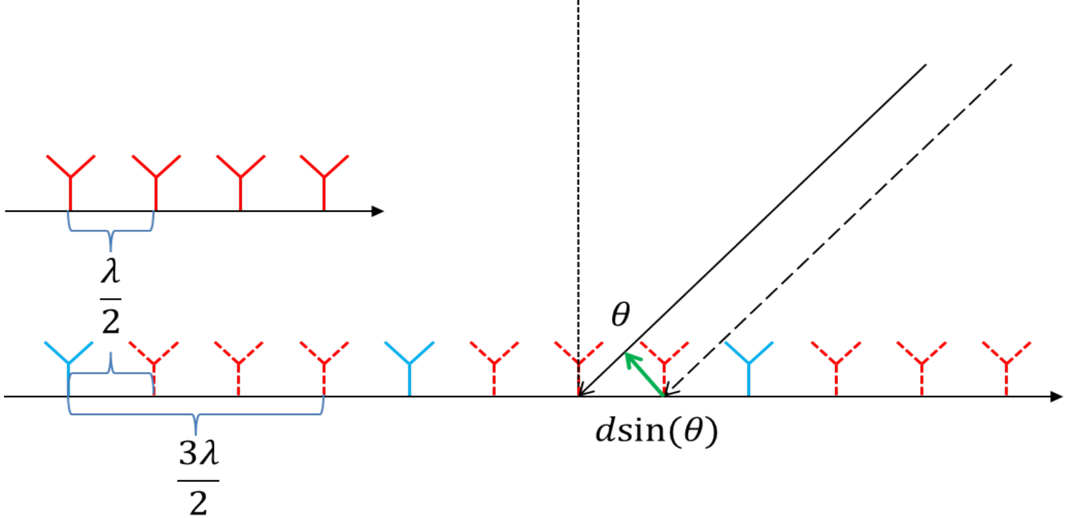


TEF810X / S32R274 Radar Chipset



Credit card size

MIMO Setup



MIMO array model

– Antenna elements: 3 transmitters and 4 receivers $M_T = 3,\ M_R = 4$

- Inter-element spacing: $d_T = 2\lambda,\ d_R = \lambda / 2$
- Steering vector:

$$a_T(\theta) = \begin{bmatrix} 1 & e^{j2\pi d_T \sin\theta/\lambda} & \cdots & e^{j2\pi(M_T-1)d_T \sin\theta/\lambda} \end{bmatrix}$$

$$a_R(\theta) = \begin{bmatrix} 1 & e^{j2\pi d_R \sin\theta/\lambda} & \cdots & e^{j2\pi(M_R-1)d_R \sin\theta/\lambda} \end{bmatrix}$$

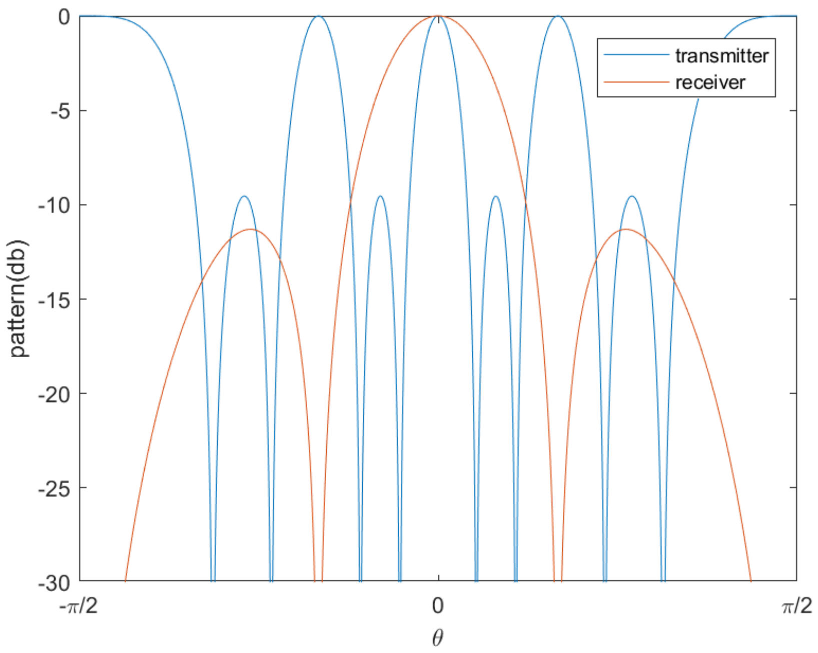
– Virtual array: 12 elements $M = M_T M_R$

- Inter-element spacing: $d = \lambda / 2$
- Steering vector: $a(\theta) = a_T(\theta) \otimes a_R(\theta) = \begin{bmatrix} 1 & e^{j2\pi d \sin\theta/\lambda} & \cdots & e^{j2\pi(M-1)d \sin\theta/\lambda} \end{bmatrix}$

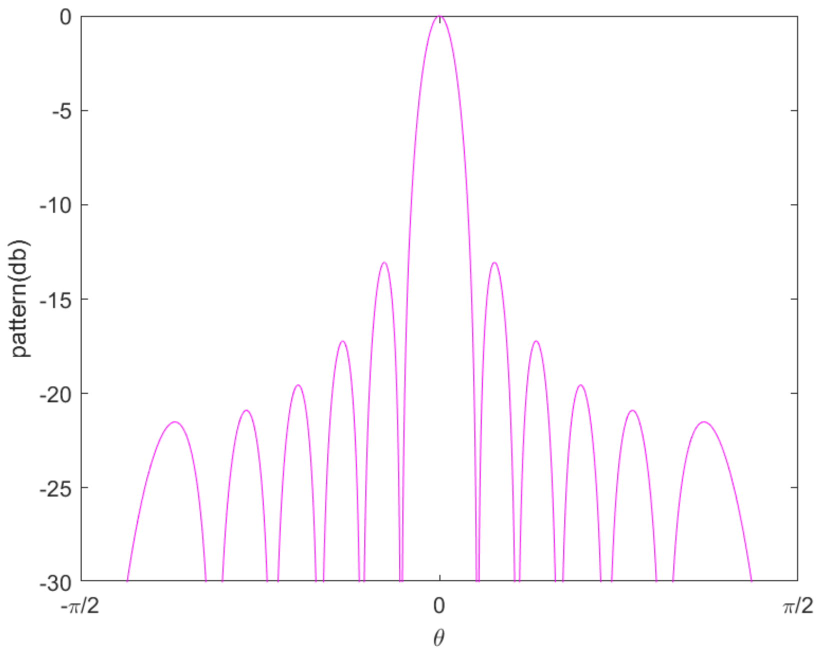
Kronecker product

Virtual Array

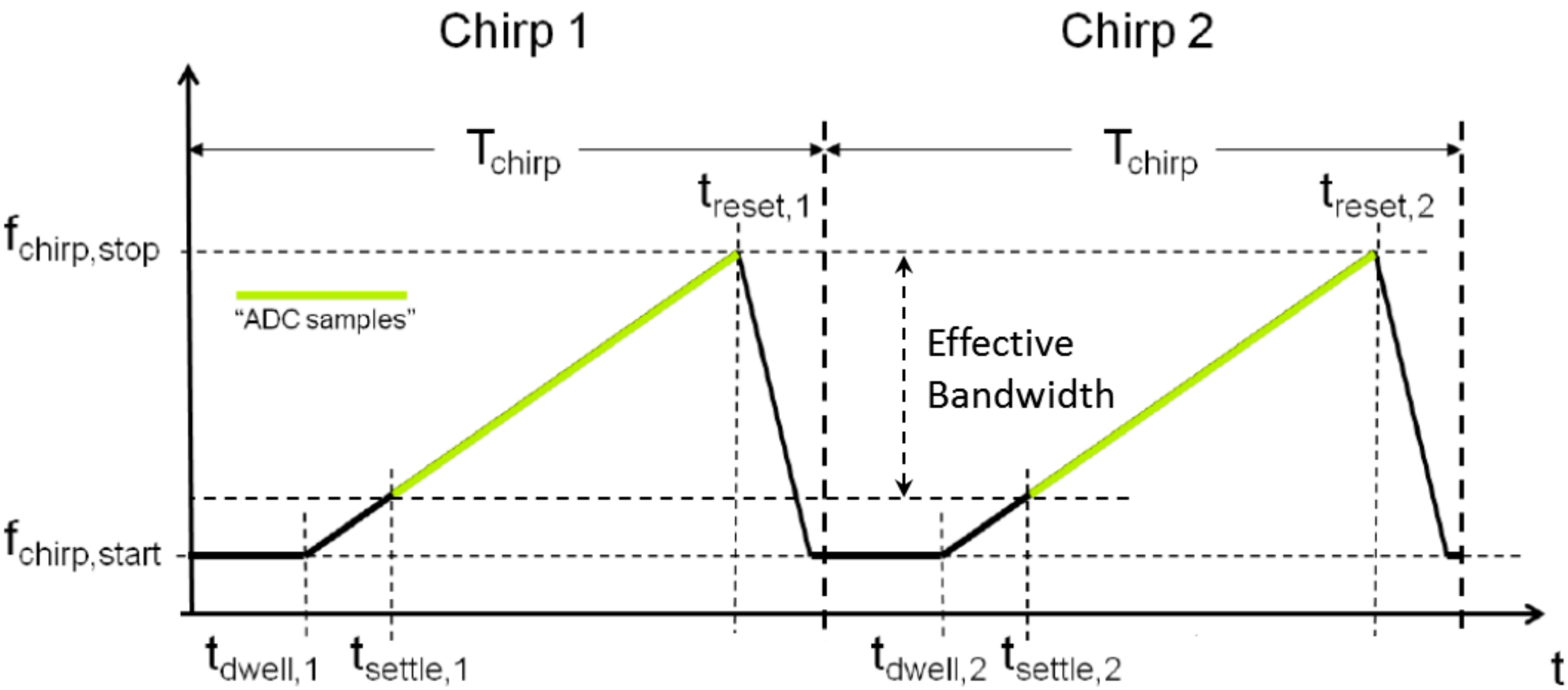
Array pattern for Tx and Rx



Effective Array pattern



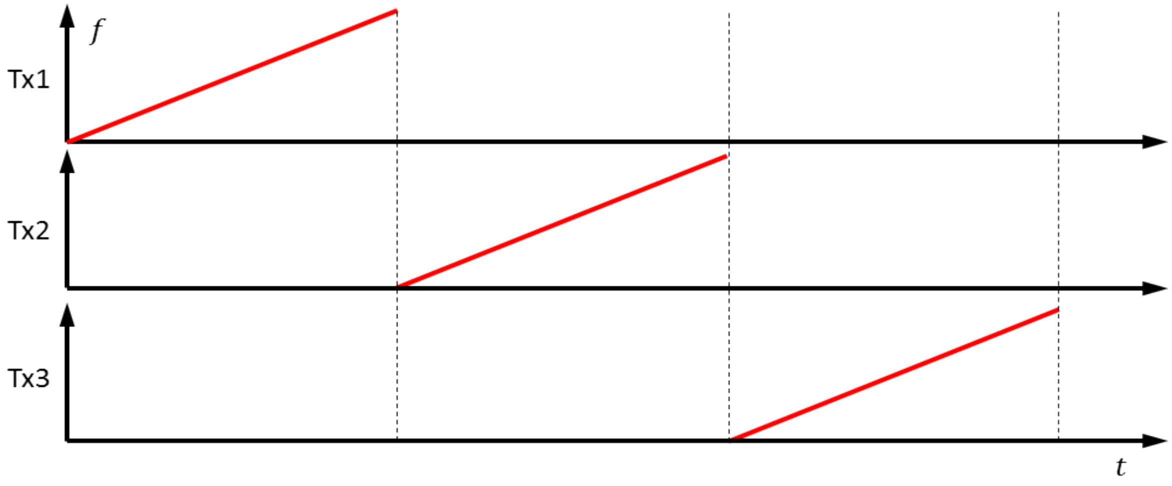
Timing is Important



TUDelft

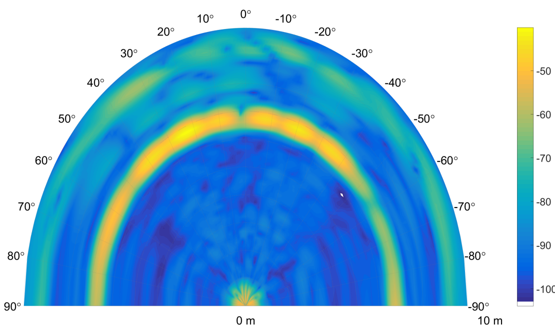
Orthogonality

- Orthogonal waveforms generation:
  - Time division
    - Sequentially transmit signals
    - Easy to implement

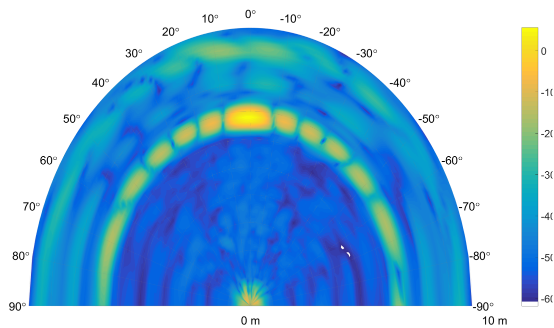


Calibration!

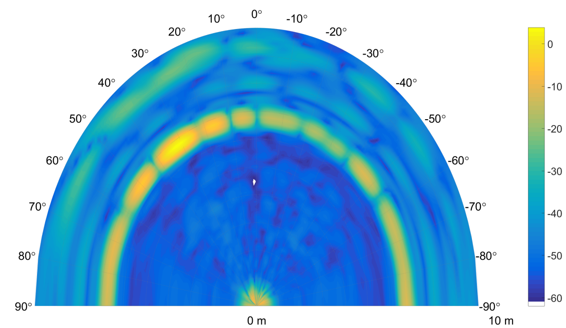
- Experimental data processing
  - Calibration:
    - Calibrate transmitter and receiver separately (in example known sources at 0 degrees is used for joint calibration)
    - Consider mutual coupling (in example neglected)



Without calibration



After calibration

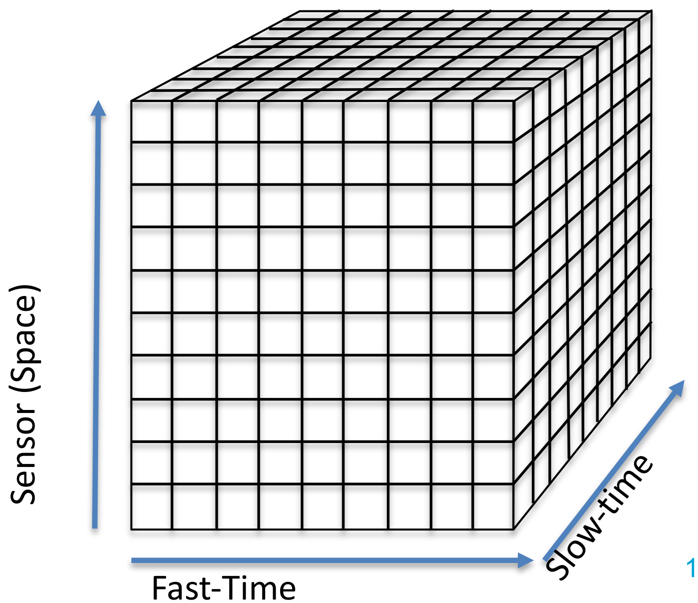


Test on -30 degree

Data Structure

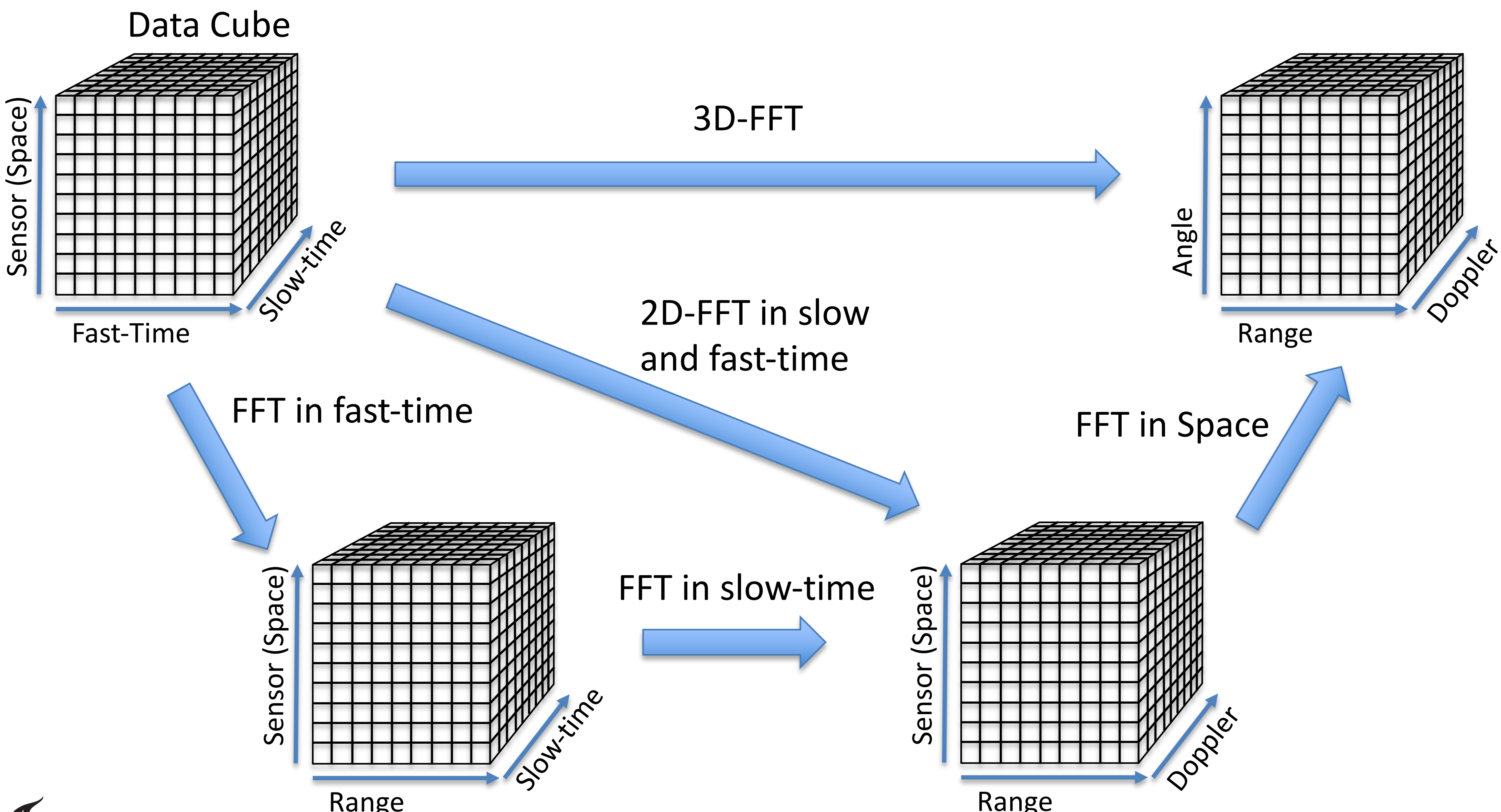
- Single Sensor: [fast-time x slow-time]
  - Read for range Doppler processing
- Multiple Sensor: [fast-time x slow-time x space]
  - Three dimensional Data
  - Ready for range Doppler and AoA

Data Cube



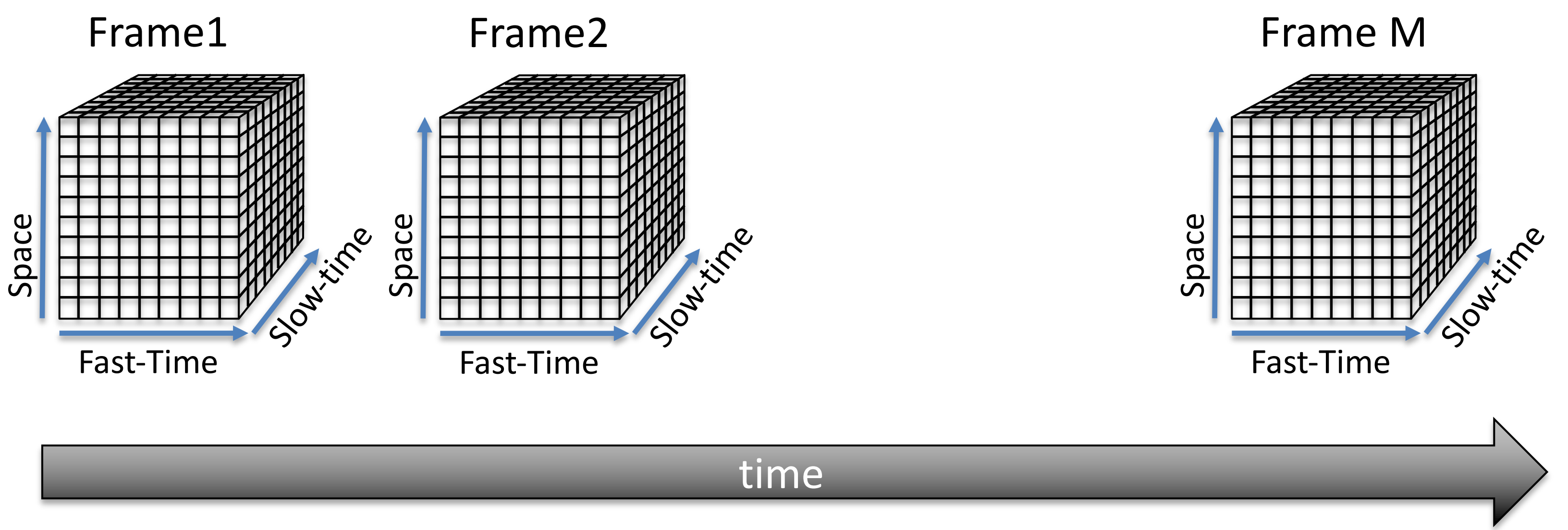
- Number of fast-time and slow-time samples usually selected as power of two.

Data Structure



Data Structure Extended

- If we collect multiple data cubes (frames) over time



- Total data is 4-D [sensors x slow-time x fast time x frame]
- Or sometimes more

Assigment-1

- **Data Name :** *Assigment1.mat*
- **Variables:** *CollectionA, CollectionB, CollectionC, CollectionD, Radar_settings*
  - *format: sensor by fast-time [12 x 1024].*
- **How to start:** Use *Example.m*
- **What to do:**
  - Plot angle vs range
  - Compute range and angular resolution
- **What to deliver:**
  - Matlab code and report

Assigment-2

- **Data Name :** *Assigment2.mat*
- **Variables:** *CollectionA, CollectionB, CollectionC, CollectionD, Radar_settings*
  - *format: sensor by fast-time [12 x 1024].*
- **How to start:** Use *Example.m*
- **What to do:**
  - Plot angle vs range
  - Compute range and angular resolution
- **What to deliver:**
  - Matlab code and report

Assignment 3

- **Data Name :** *Walkin_towards_radar_along_beam.mat*
- **How to start:** Use *Example2.m and use sample data*
- **What to do:**
  - Create a range-Doppler movie
  - Create micro-Doppler signature
  - Create a video for angle-range plot
- **What to deliver:**
  - Matlab code and report

Contact Persons

- Dr. Faruk Uysal
  email: f.uysal@tudelft.nl
  Room: HB 21.280

TU Delft