ET4169- Microwaves, Radar and Remote Sensing

Automotive Radar Lab

Faruk Uysal

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

TU Delft

Learning Objectives

- Observe radar signatures
- Observe range-Doppler processing
- Understand MIMO and Array Processing
- Apply calibration
- Apply Angle of Arrival (AoA)

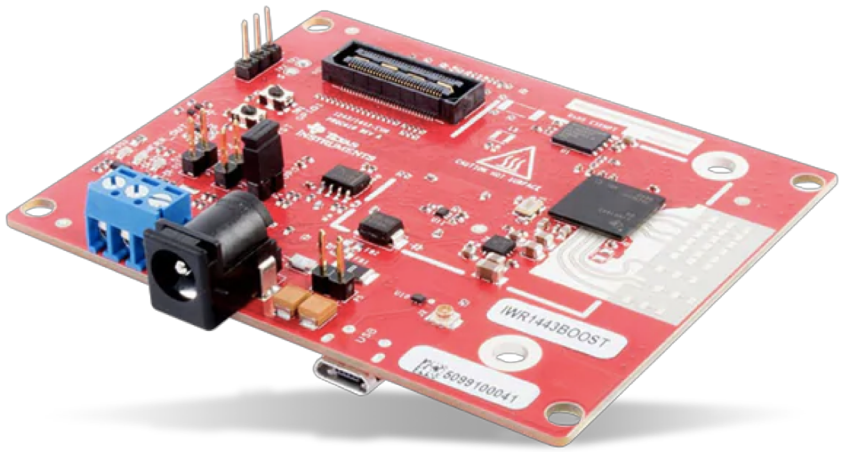
Lab Assignments

- Part-I : **In Lab**
  - Observe radar signatures and different radar signal processing methods real-time.
- Part-II : **Homework**
  - Apply array calibration and angle of arrival estimation

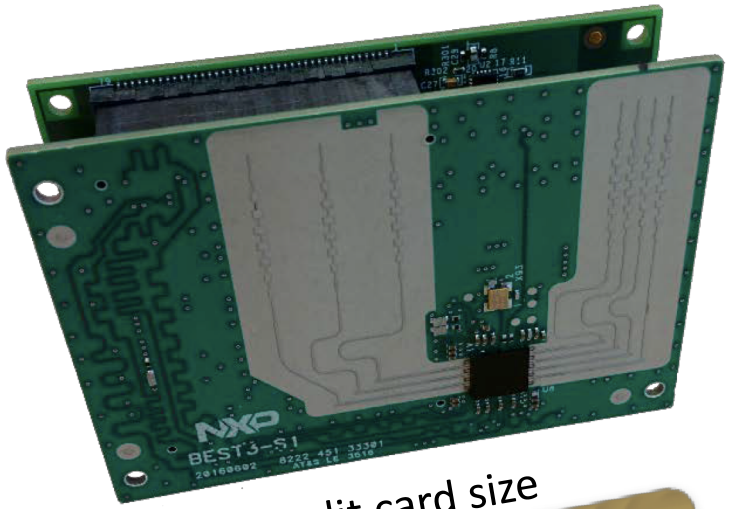
Equipment

TEXAS INSTRUMENTS

IWR1443BOOST



NXP TEF810X / S32R274 Radar Chipset



Credit card size

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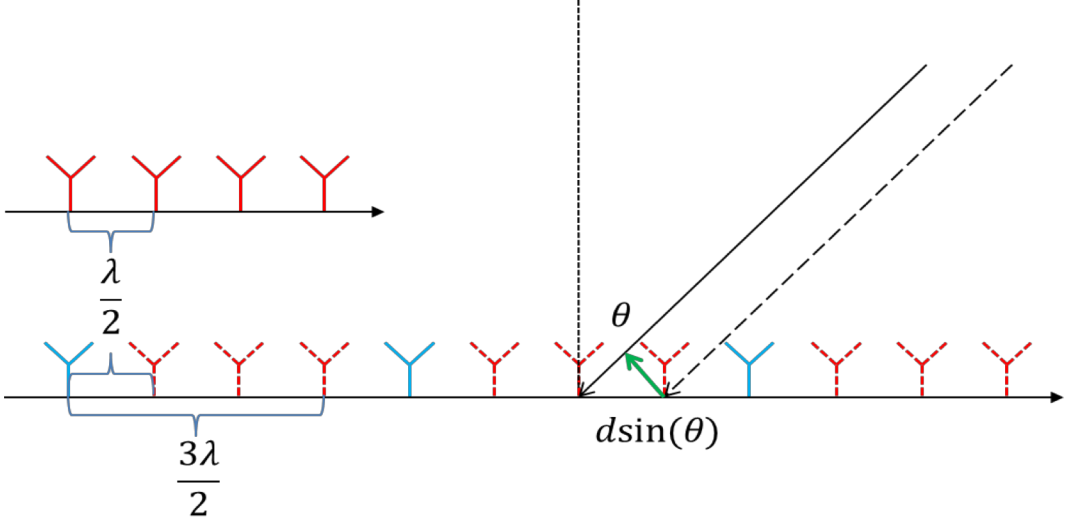
MIMO Setup

- Example: NXP Configuration



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:

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

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

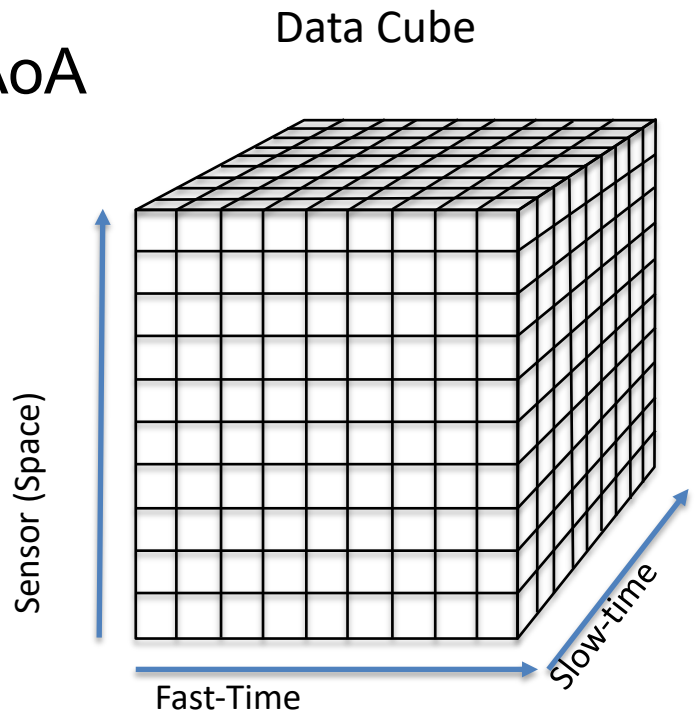
– Virtual array: 12 elements $M = M_T M_R$

- 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

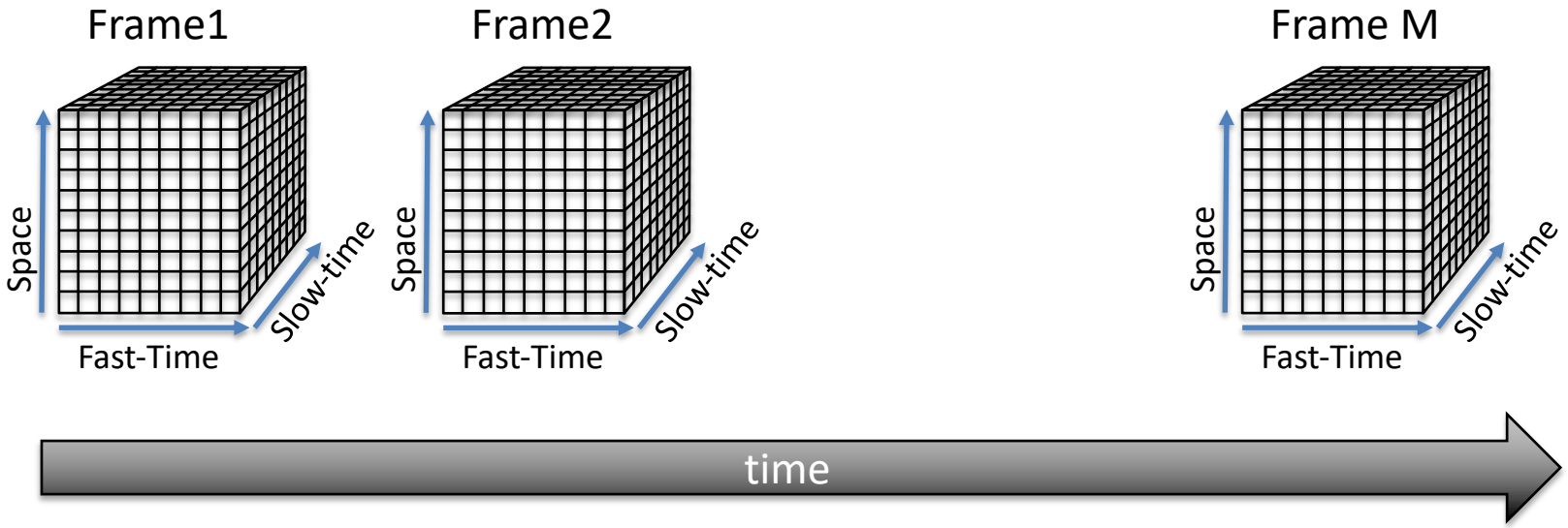
Data Structure

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



Data Structure Extended

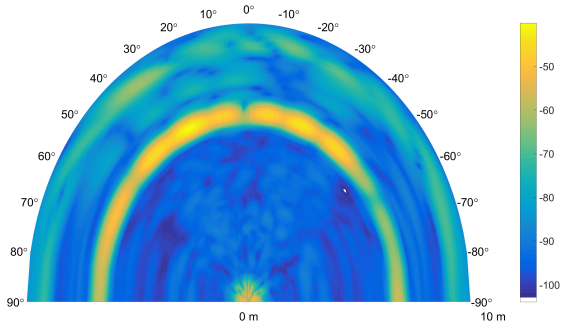
- If we collect multiple data cubes (frames) over time



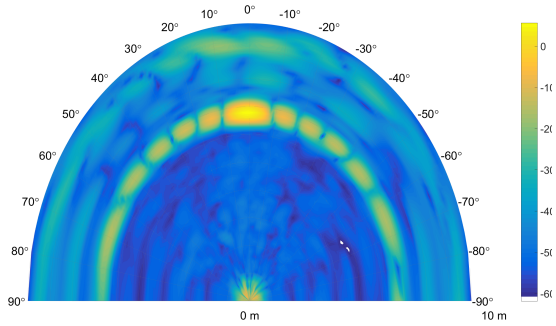
- Total data is 4-D [sensors x slow-time x fast time x frame]
- Or sometimes more

Calibration!

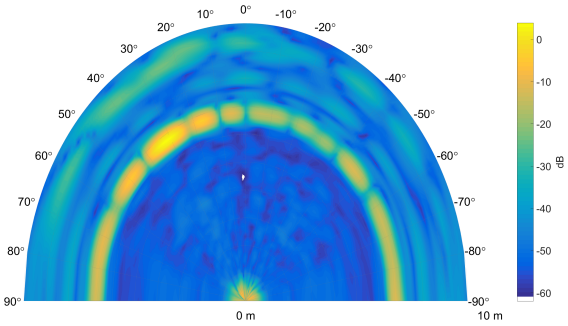
- Experimental data processing
  - Calibration:
    - Calibrate transmitter and receiver separately (in example known sources at 0 degrees is used for joint calibration)
    - Basic calibration calibration (neglect mutual coupling)
    - Proper calibration addresses mutual coupling



Without calibration



After calibration



Test on -30 degree

Calibration Procedure

Follow the procedure to calibrate your system

1. Collect data at broadside (0 degree) for a given range

   Data=[fast-time , slow-time , space]

2. Achieve range profiles

   RangeProfiles=[Range , slow-time , space]

1. Extract the range data for each virtual array

   Sensor = [target Range x single slow-time x space]

   Sensor = [space]

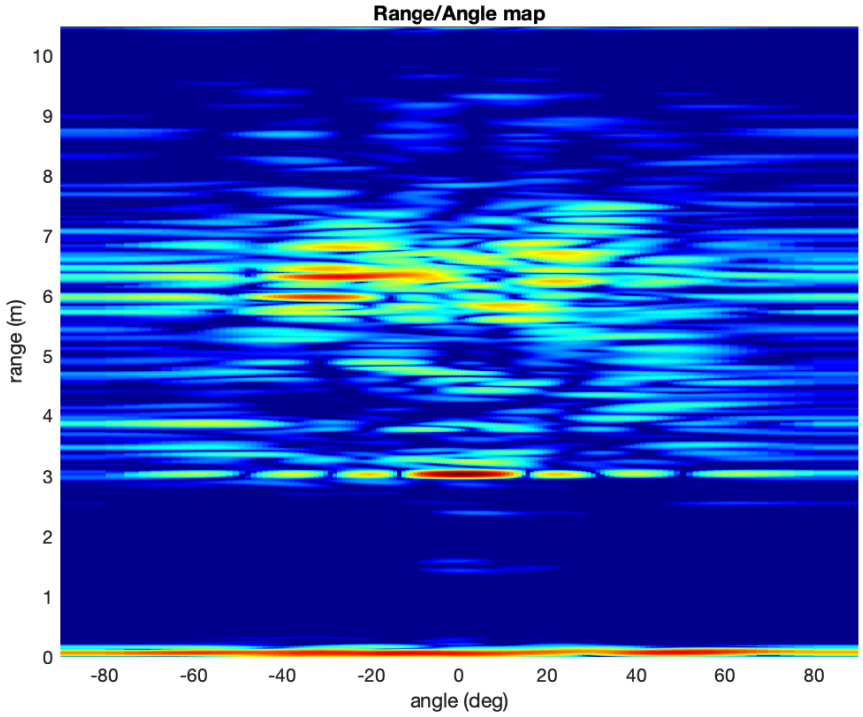
2. Use complex conjugate of this vector for a first order calibration coefficient.

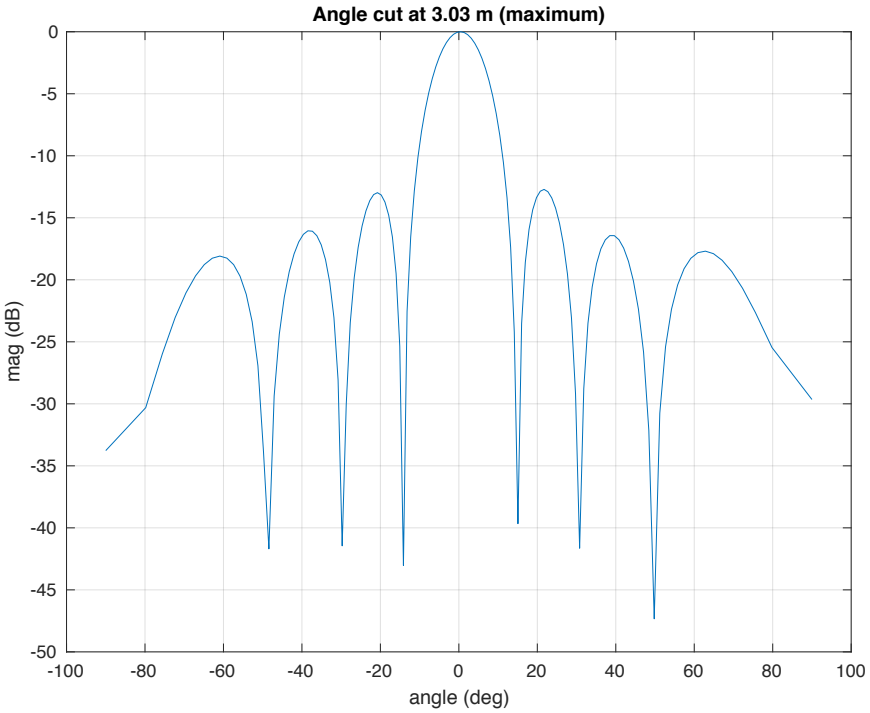
   Calib_Coef=1/ (Sensor)

Assigment-2

- **Data Name :** *Collected by Students*
- **How to start:** Use readTIRawData_CCS_capture_demo*.m*
- **What to do:**
  - Read your data using provided Matlab script
  - identify which correction coefficient belongs to your radar
  - Create your own calibration coefficient
- **What to deliver:**
  - Matlab code and report

Assigment-2

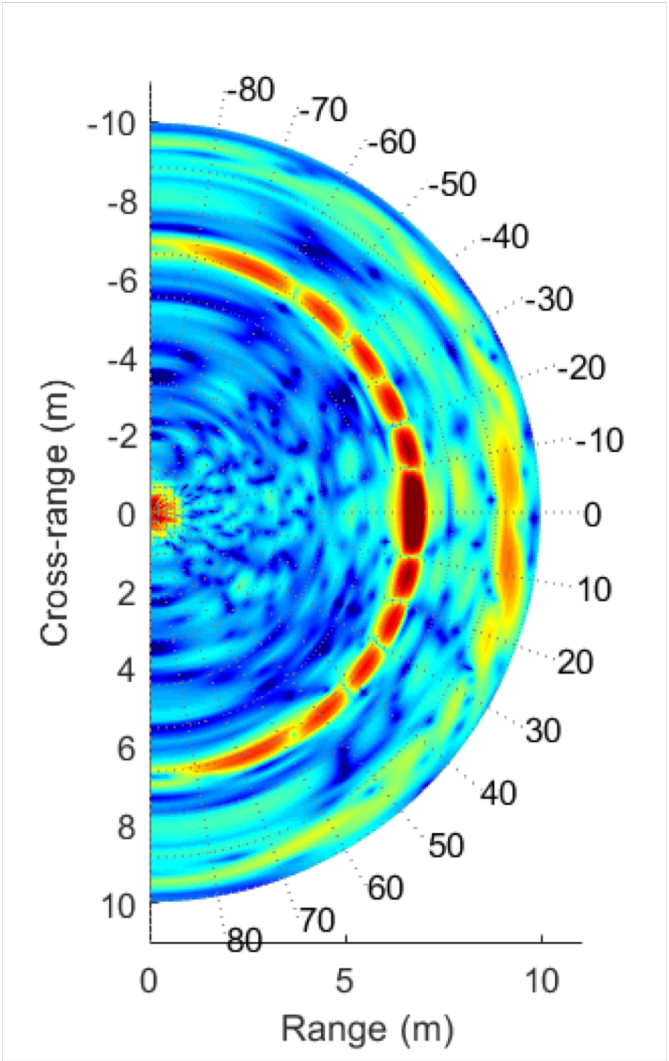

Range/Angle map
range (m)
angle (deg)
0
1
2
3
4
5
6
7
8
9
10
-80
-60
-40
-20
0
20
40
60
80

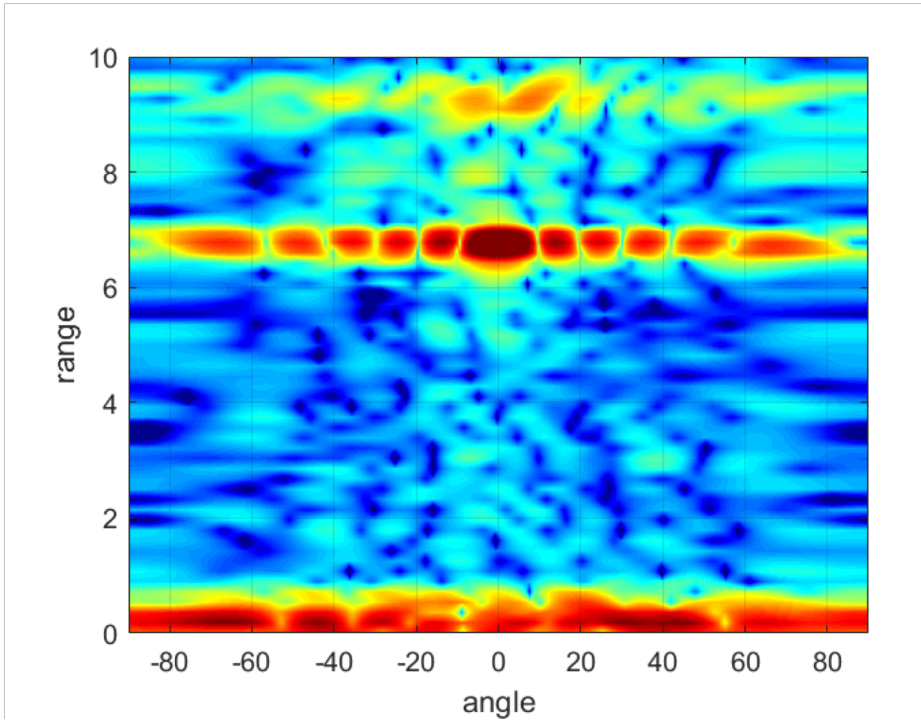

Angle cut at 3.03 m (maximum)
mag (dB)
angle (deg)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-100
-80
-60
-40
-20
0
20
40
60
80
100

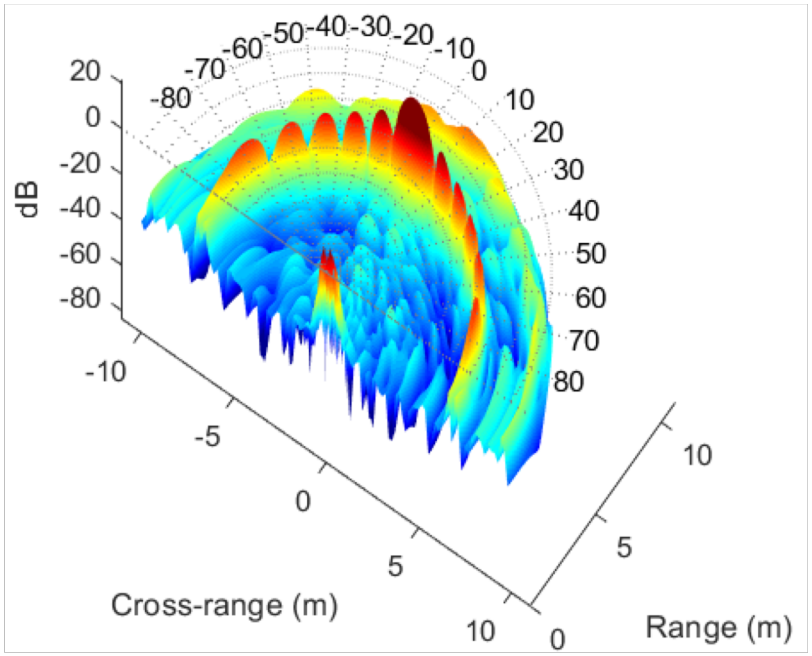
Assigment-3

- **Data Name :** *Assigment3.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-3


Cross-range (m)
Range (m)
-80
-70
-60
-50
-40
-30
-20
-10
0
10
20
30
40
50
60
70
80

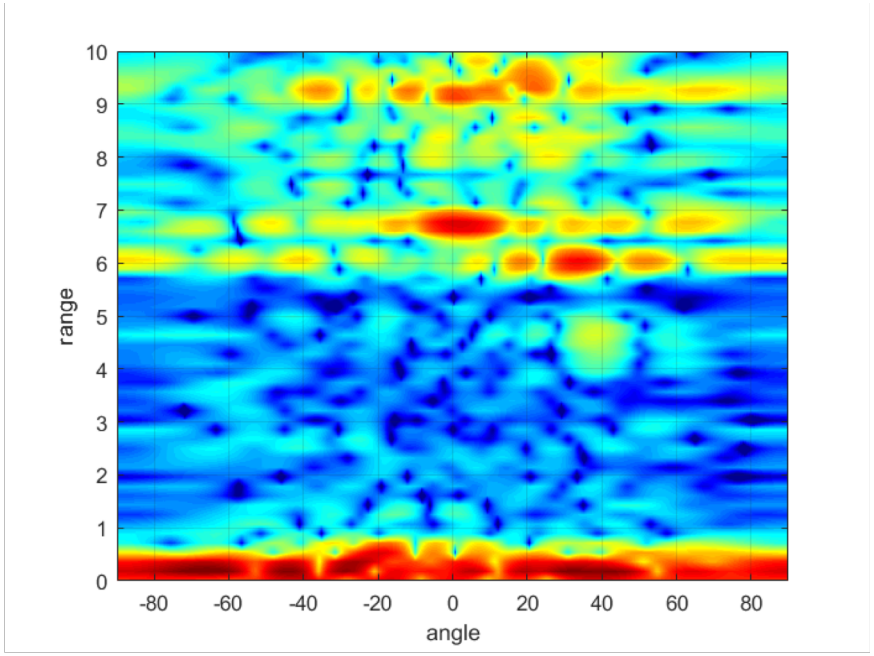

range
angle

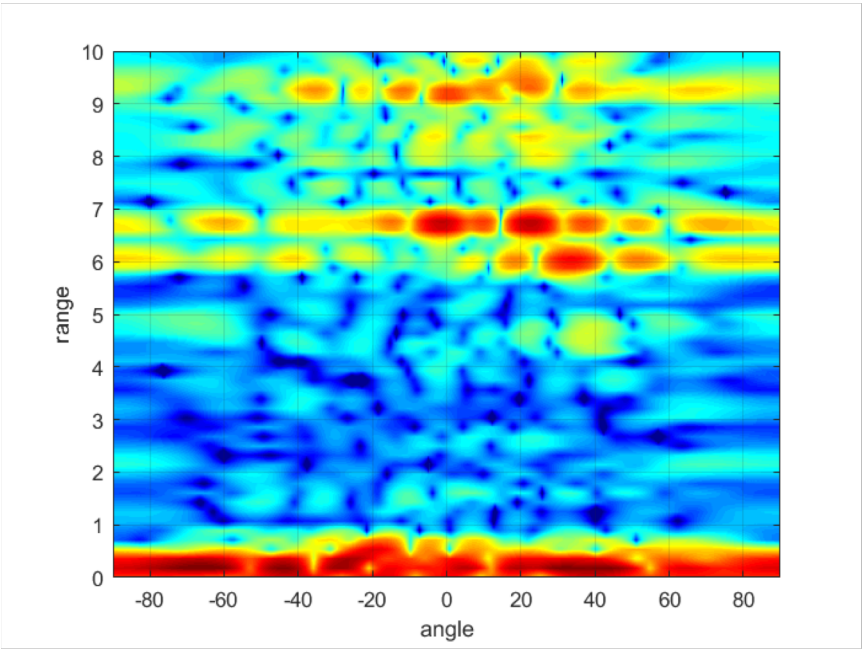

dB
Cross-range (m)
Range (m)

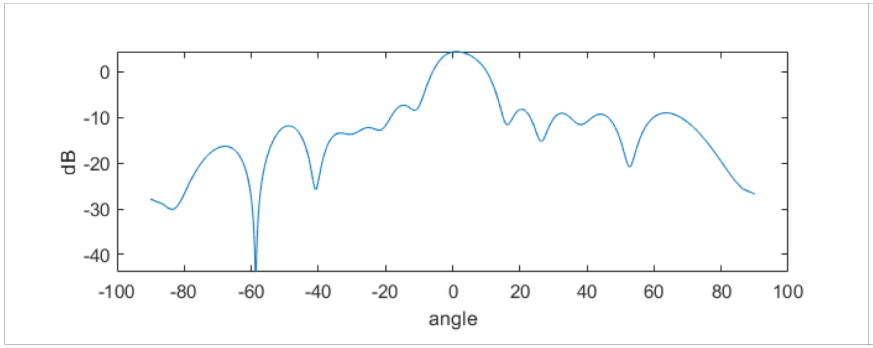
Assigment-4

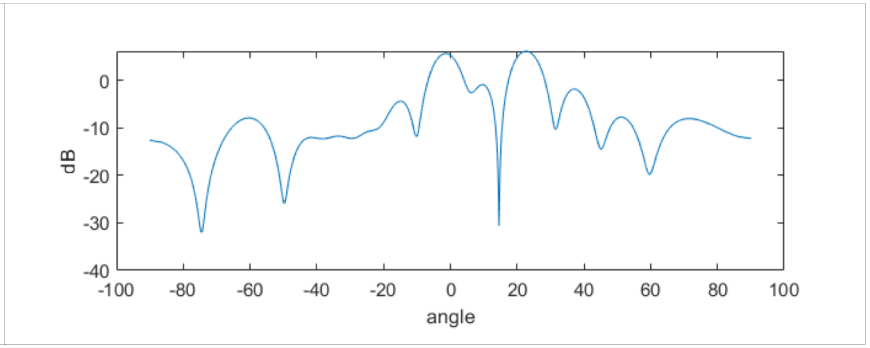
- **Data Name :** *Assigment4.mat*
- **Variables:** *CollectionA, CollectionB, CollectionC, CollectionD, Radar_settings*
  - *format: sensor by fast-time [12 x 1024].*
- **How to start:** Use *Example.m*
- **What to do:**
  - Plot angle vs range
  - Compute range and angular resolution
- **What to deliver:**
  - Matlab code and report

Assigment-4


range
angle
10
9
8
7
6
5
4
3
2
1
0
-80
-60
-40
-20
0
20
40
60
80


range
angle
10
9
8
7
6
5
4
3
2
1
0
-80
-60
-40
-20
0
20
40
60
80


dB
angle
0
-10
-20
-30
-40
-100
-80
-60
-40
-20
0
20
40
60
80
100


dB
angle
0
-10
-20
-30
-40
-100
-80
-60
-40
-20
0
20
40
60
80
100

Contact Persons

- Dr. Faruk Uysal

  email: f.uysal@tudelft.nl

  Room: HB 21.280