

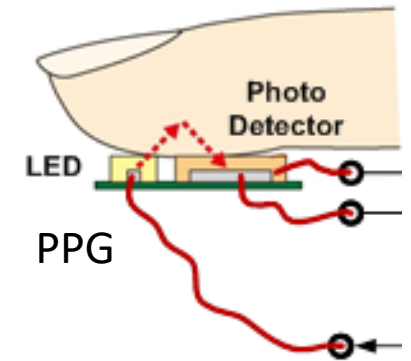
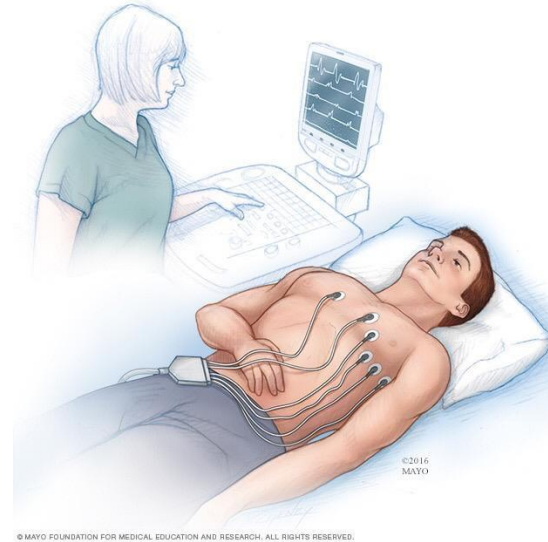
Contactless Detection of Physiological Signal using a 4-Transmitter Phased Array Ultrasound System

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Advisor : Men-Tzung Lo (羅孟宗) 、Chen Lin (林澂)

Introduction

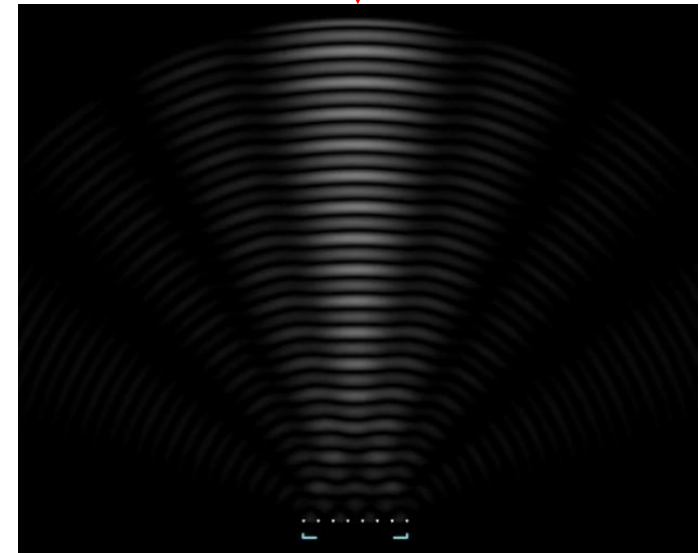
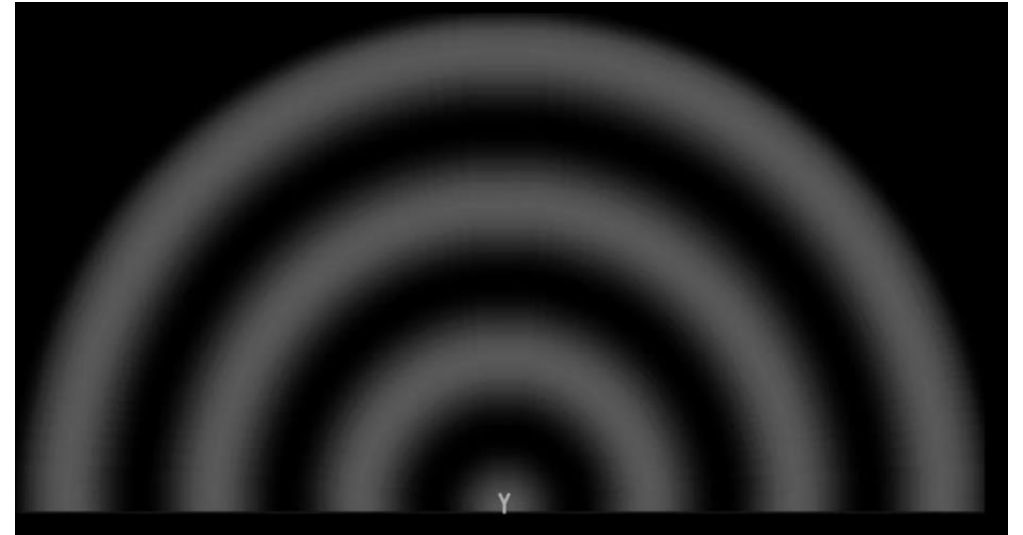
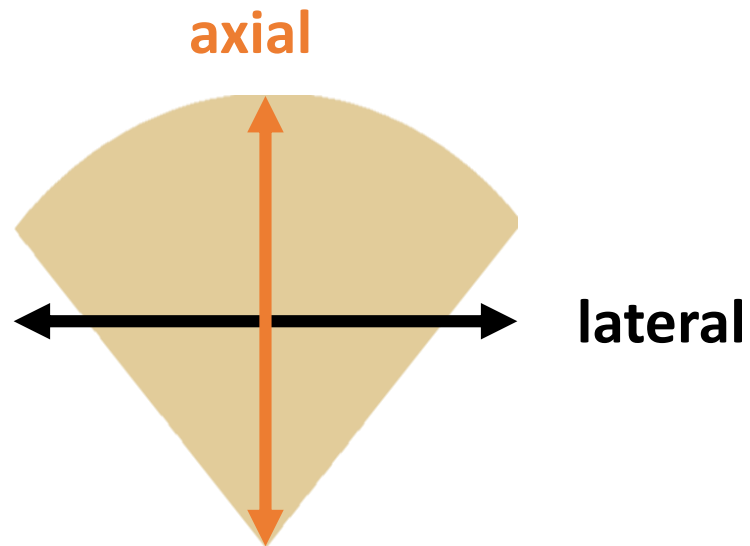
- Medical need : heart rate monitor, continuous monitor, sleep apnea
- Traditional method(contact)
 - 1) ECG
 - 2) PPG
 - 3) Nose flow detector
- Non-contact method
 - 1) Ultrasound
 - 2) Radar
 - 3) camera



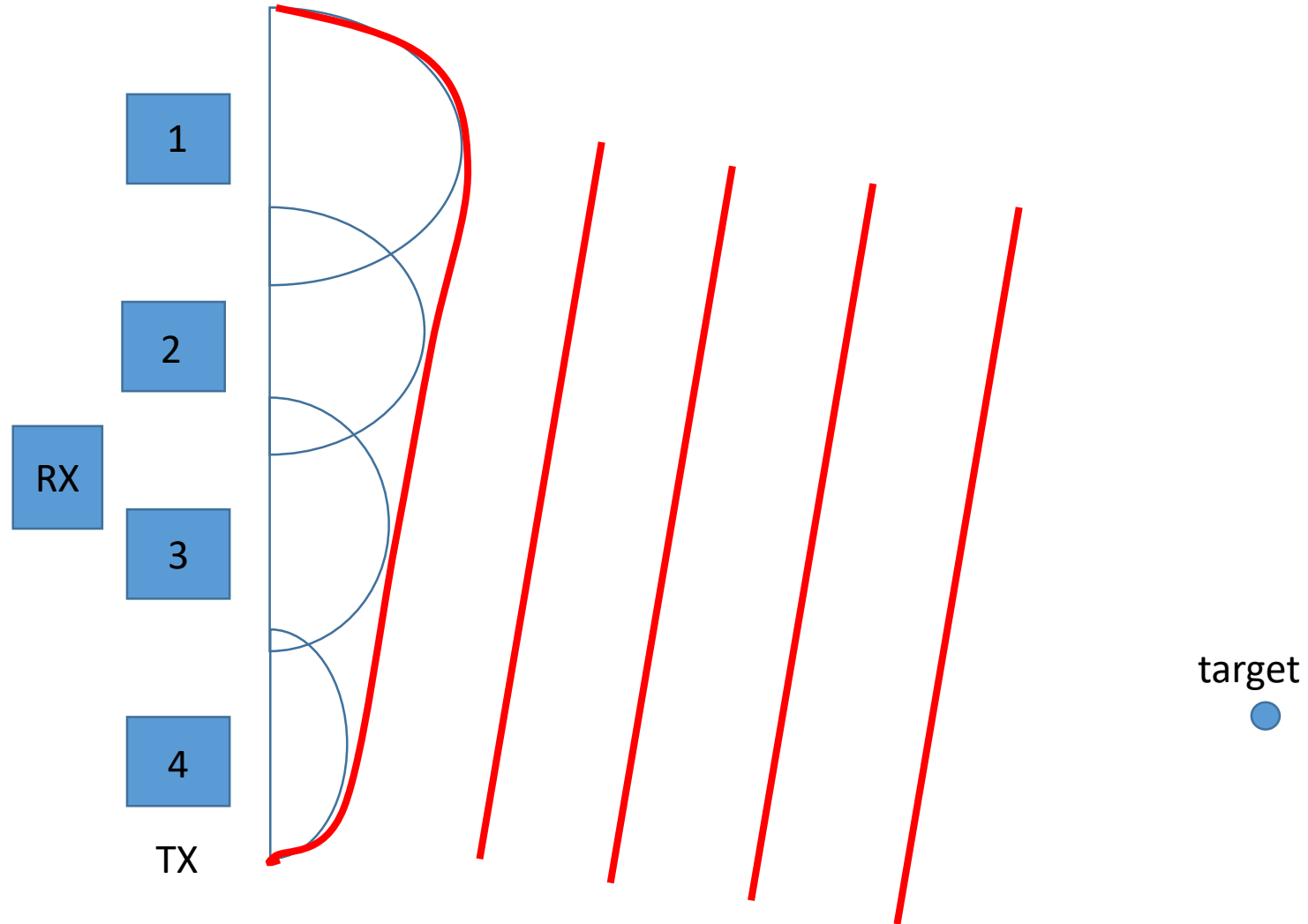
Desired specification

Axial and lateral resolution :

- Axial : displacement error around 1mm
- Lateral : phase error around 0.05 radian (3°)

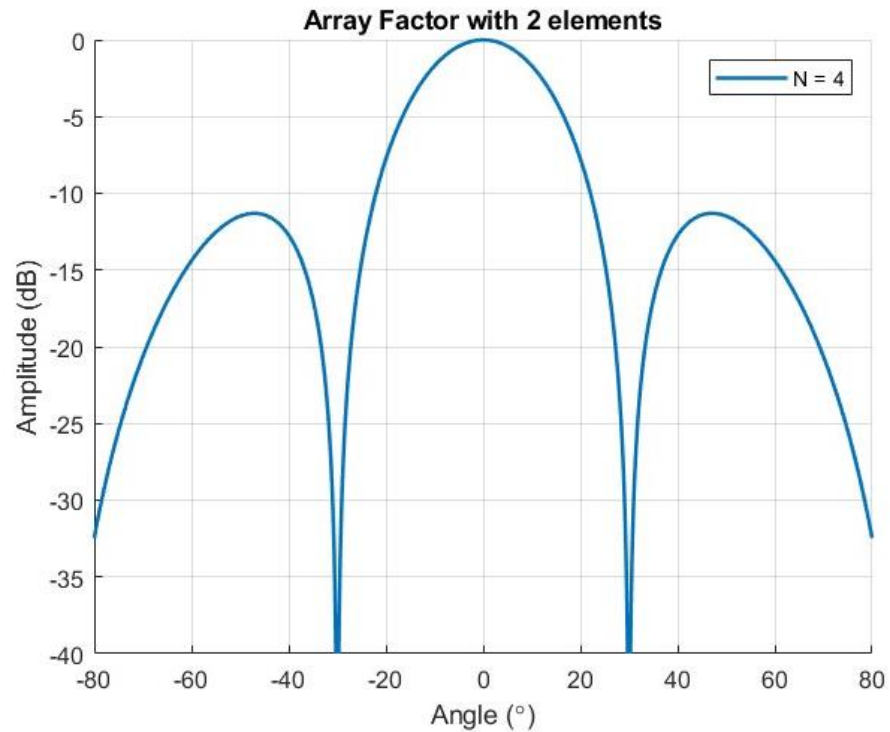


Phased array antenna

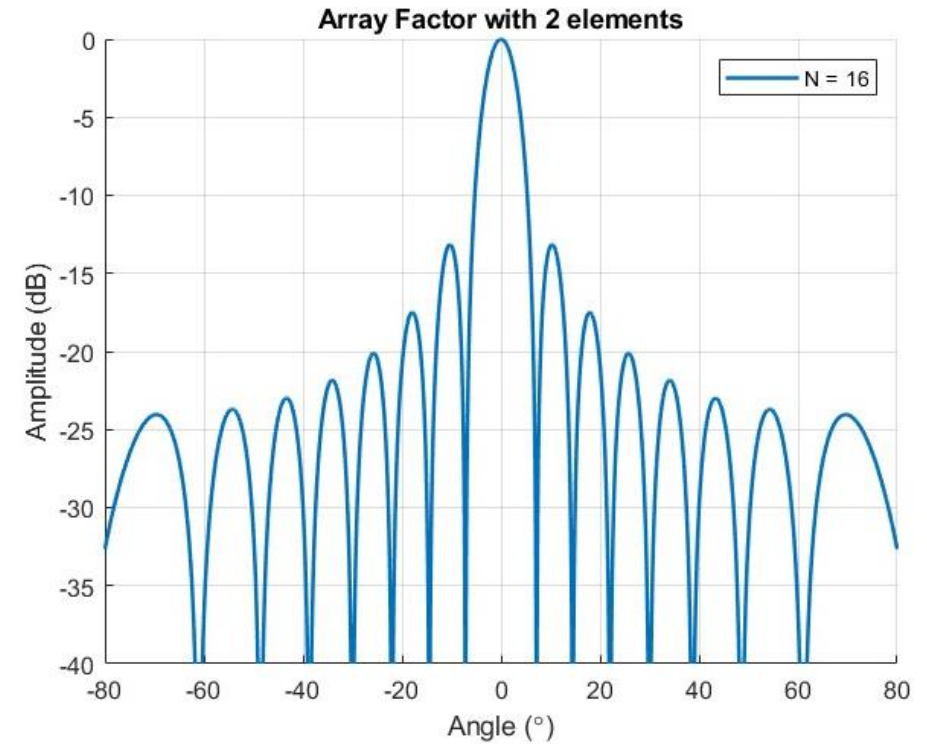


Phased array antenna

$N = 4$

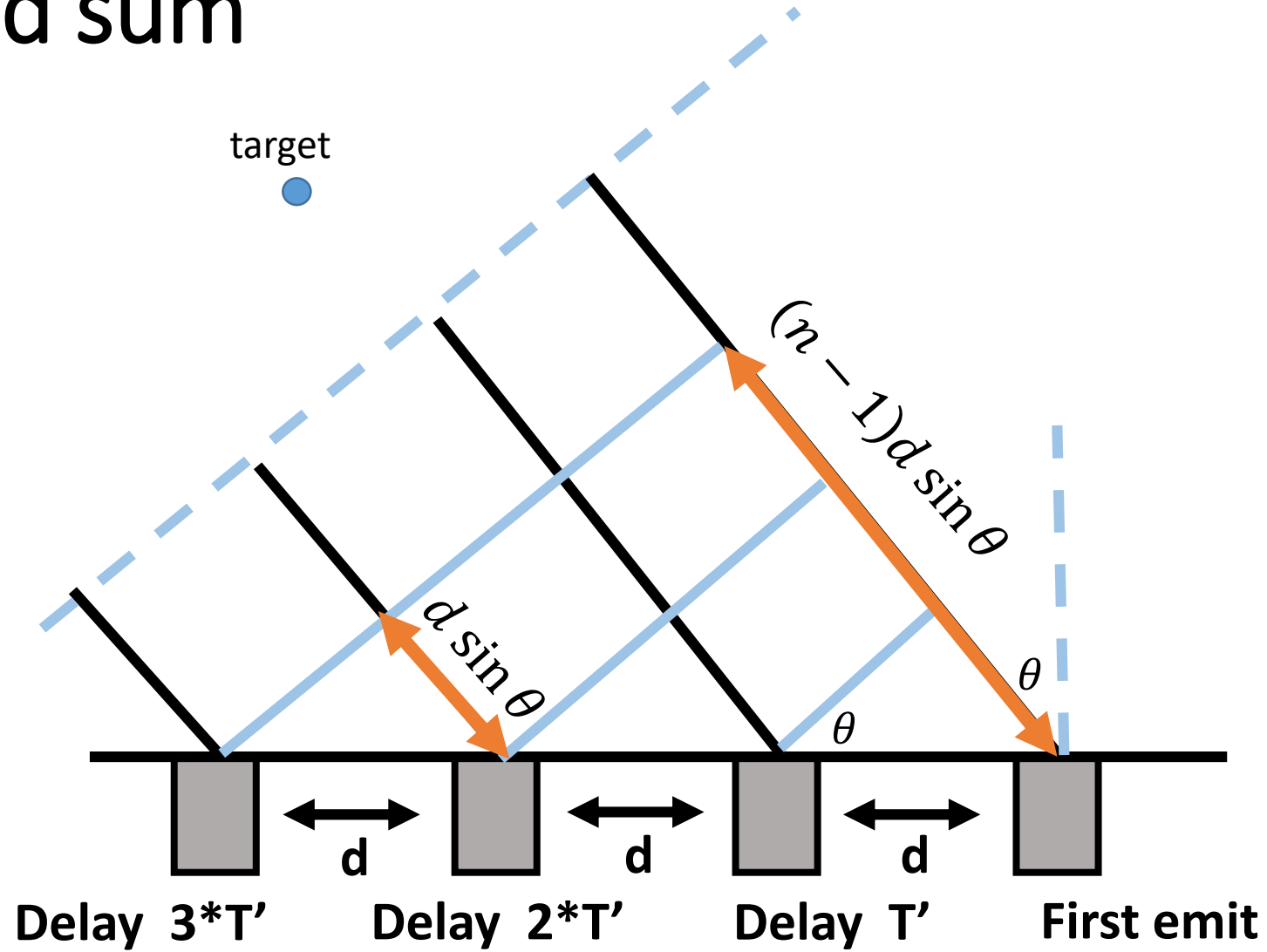


$N = 16$



Elements spacing $d = \lambda/2$

Delay and sum



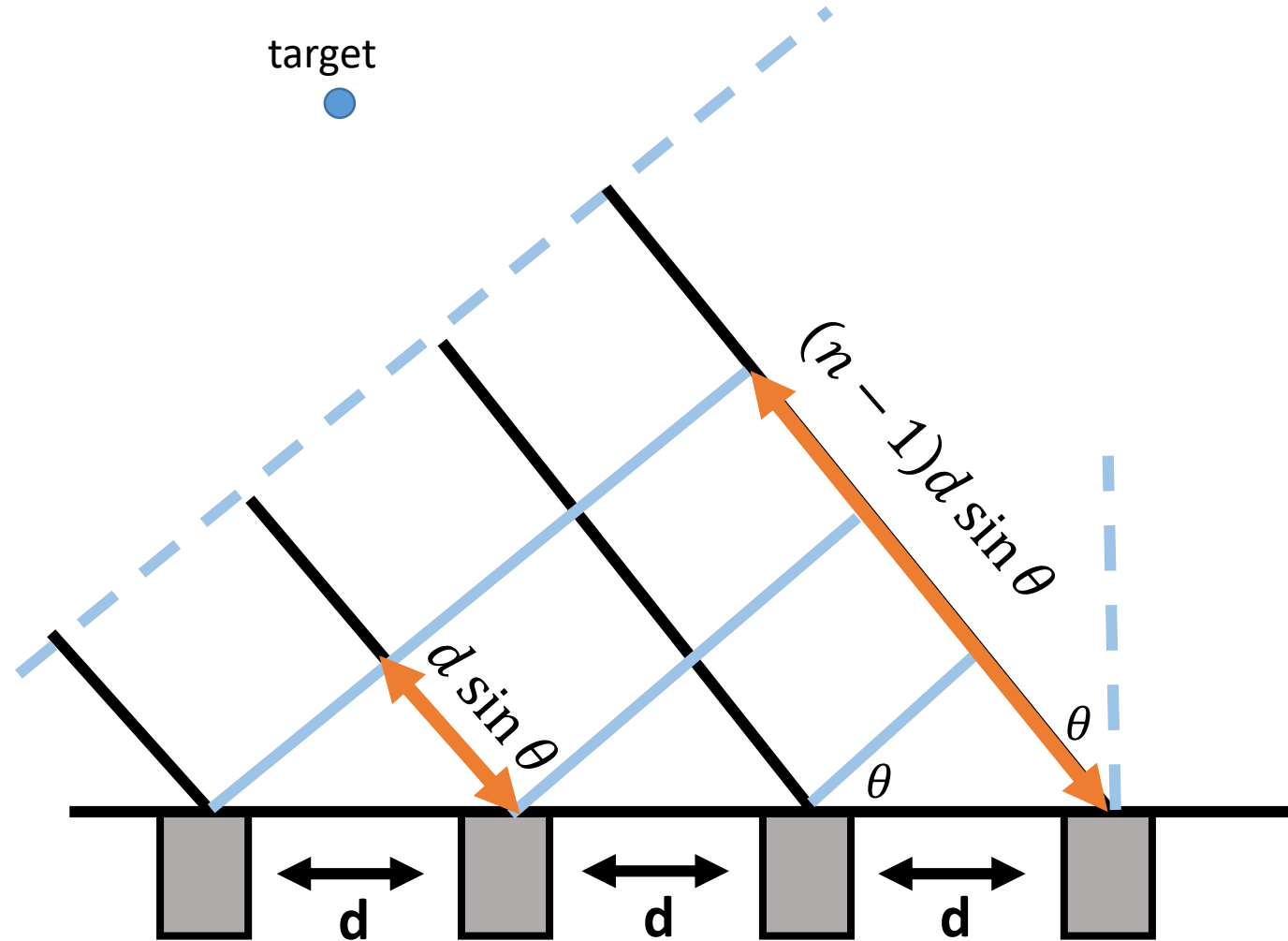
Delay and sum

$$\Delta\phi = \frac{2\pi d \sin \theta}{\lambda} \quad (2\pi = \lambda) \quad \leftarrow$$

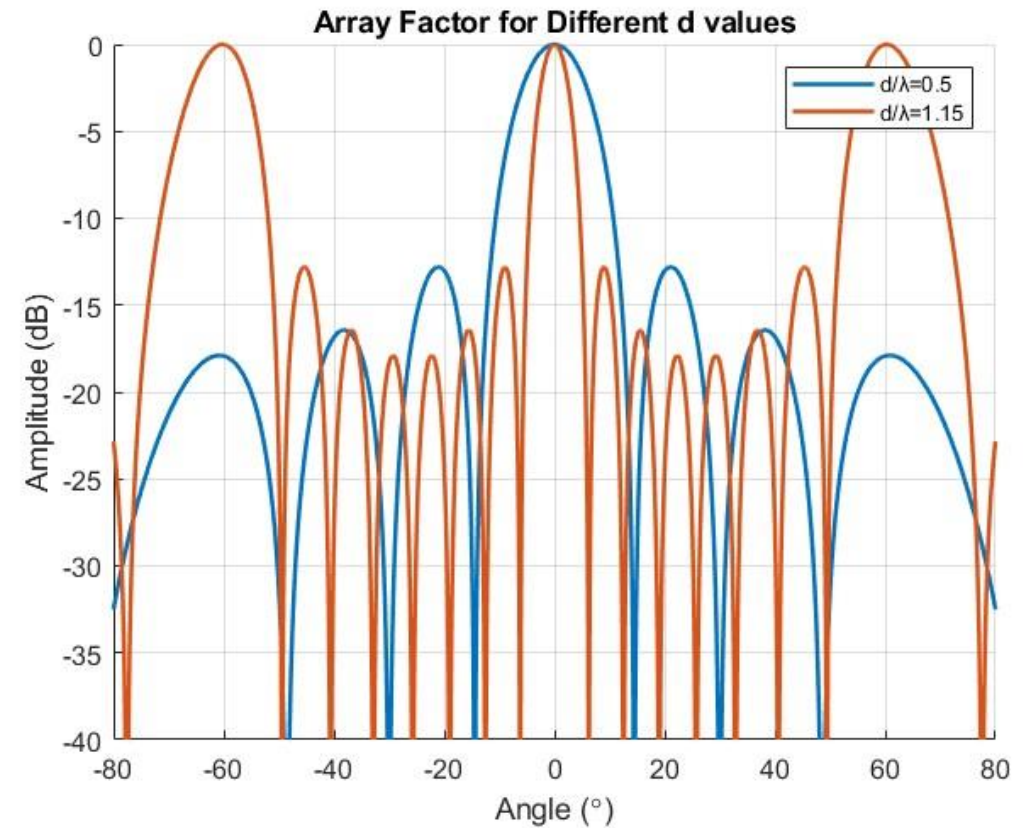
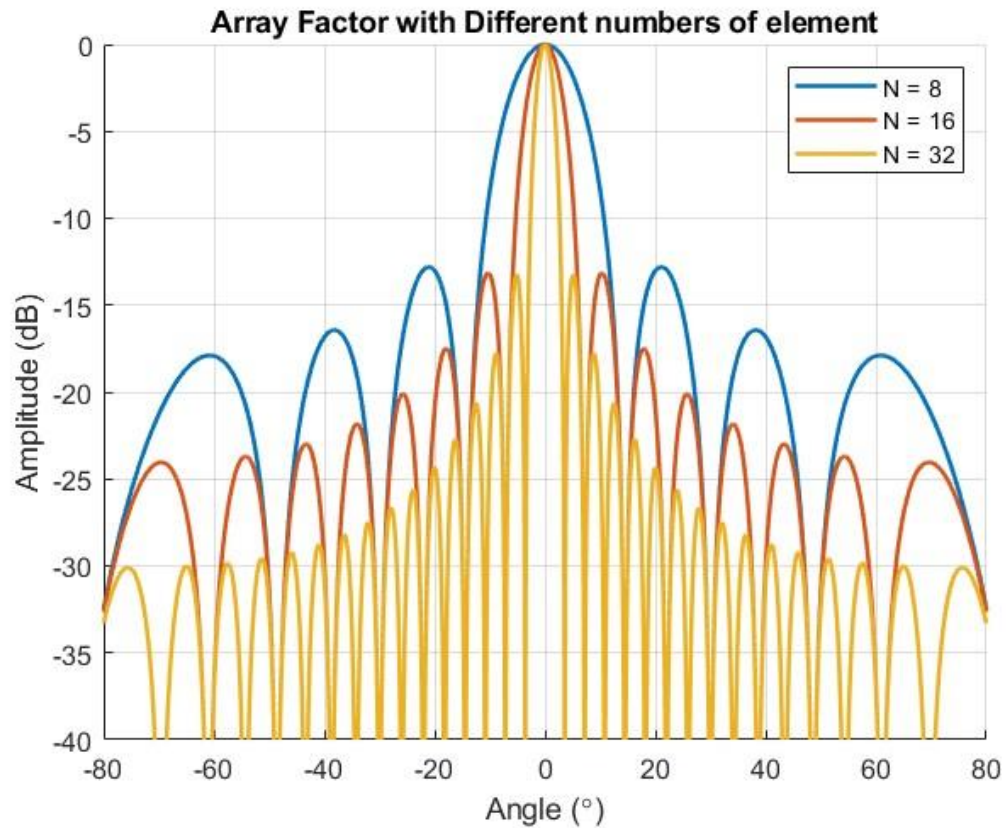
$$\theta = \sin^{-1} \left(\frac{\Delta\phi \lambda}{2\pi d} \right)$$

$$\Delta\phi = 2\pi f \Delta t$$

$$\theta = \sin^{-1} \left(\frac{2\pi f \Delta t \lambda}{2\pi d} \right) \quad \leftarrow$$

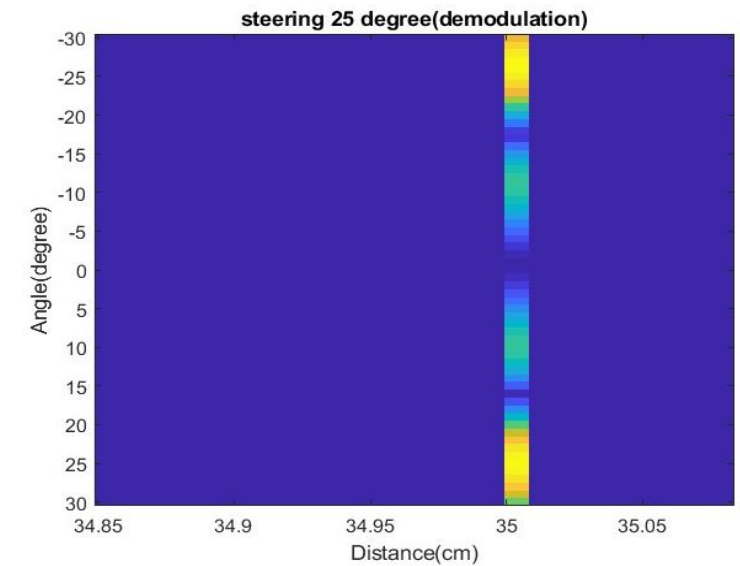
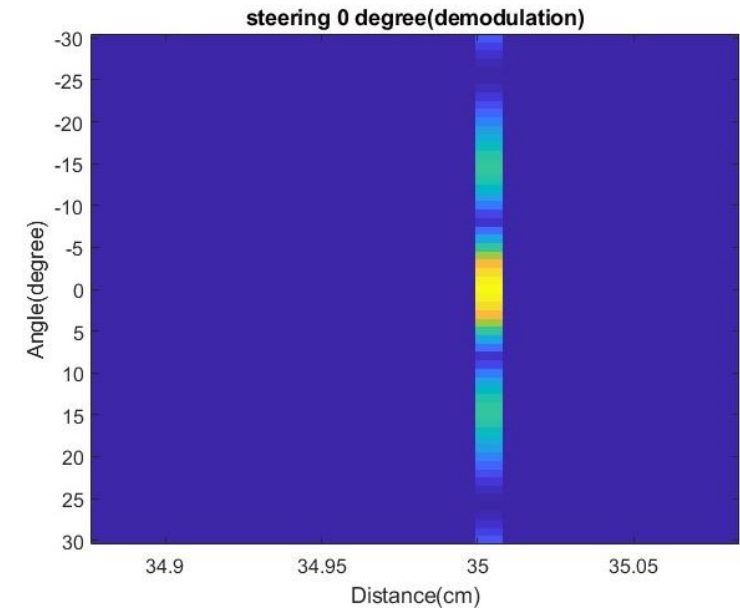
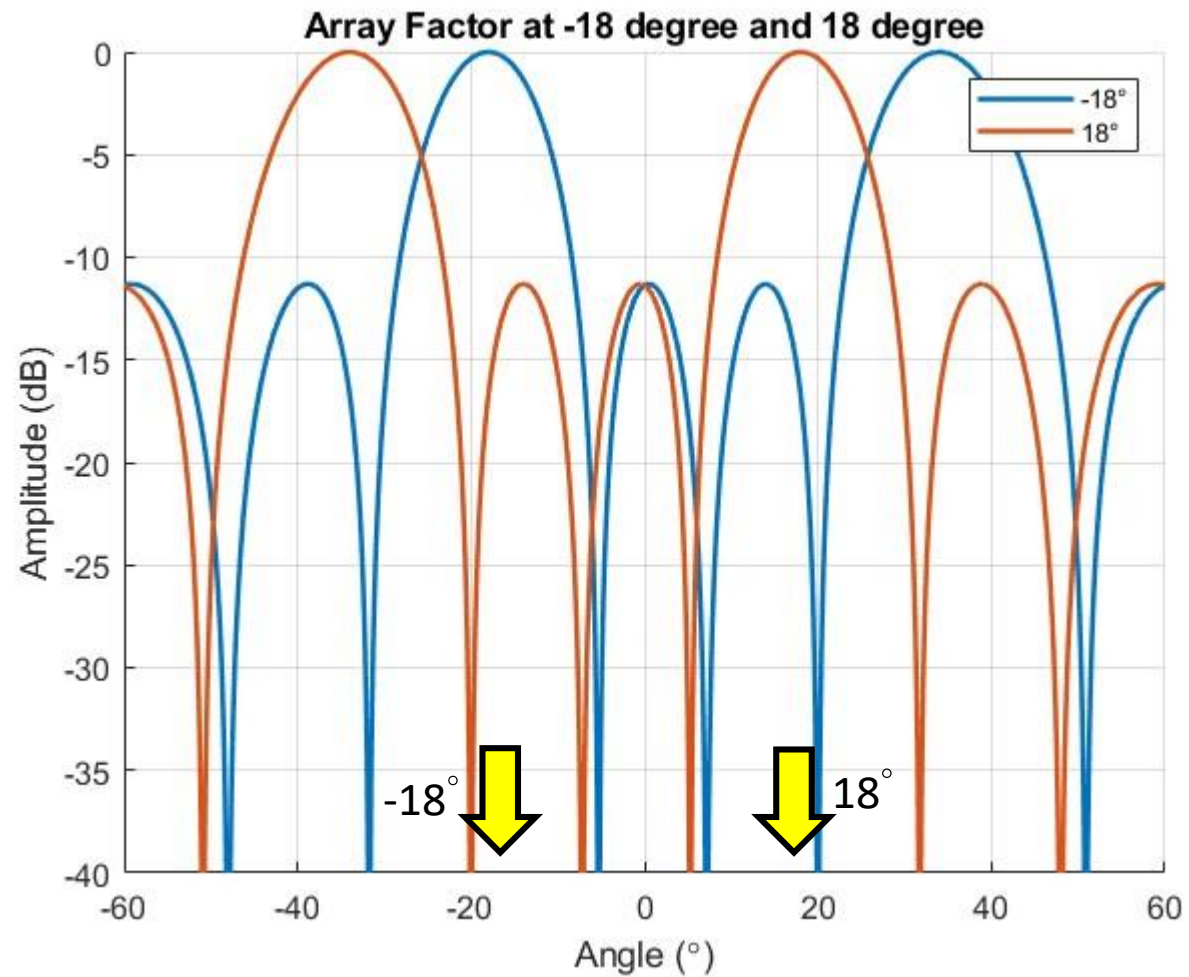


Radiation pattern

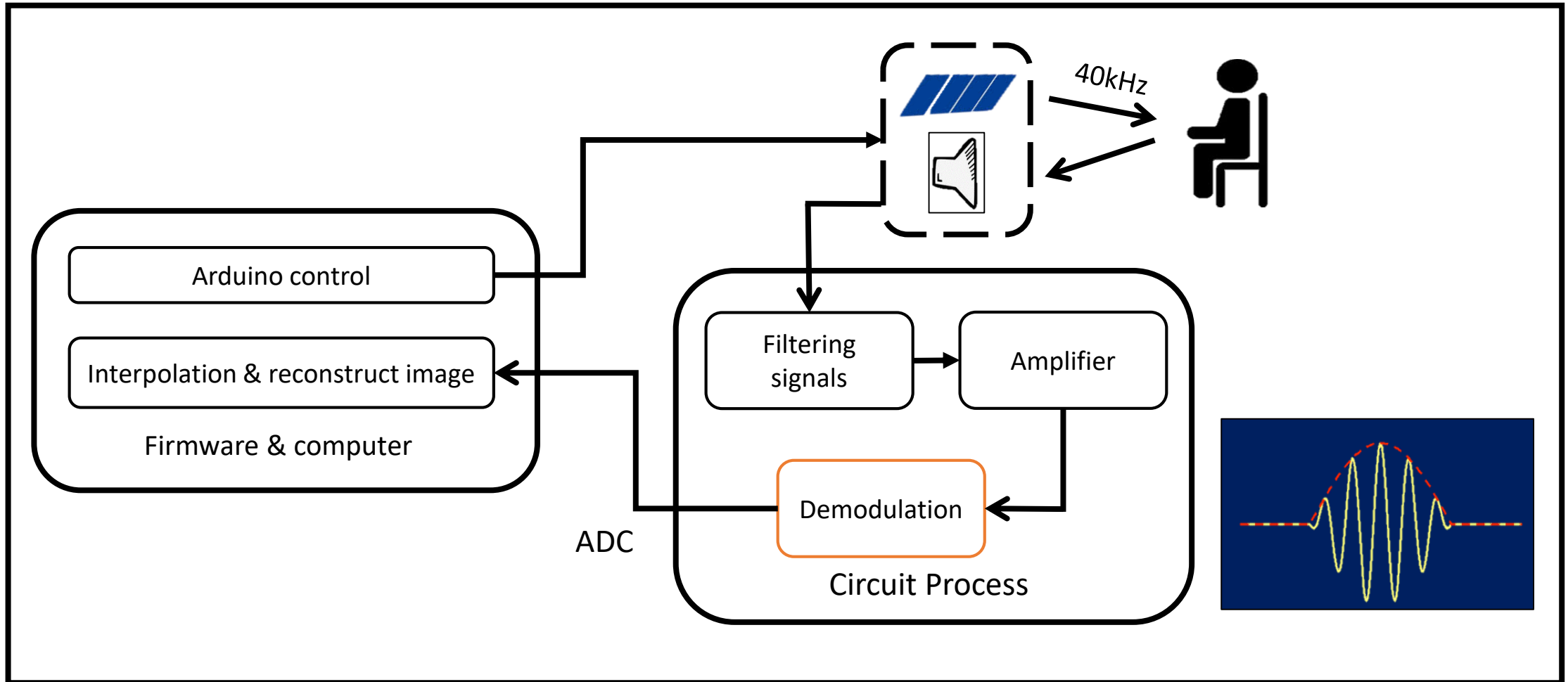


$d = 0.5\lambda$ vs $d = 1.15\lambda$

Simulation



Block diagram : phased array system

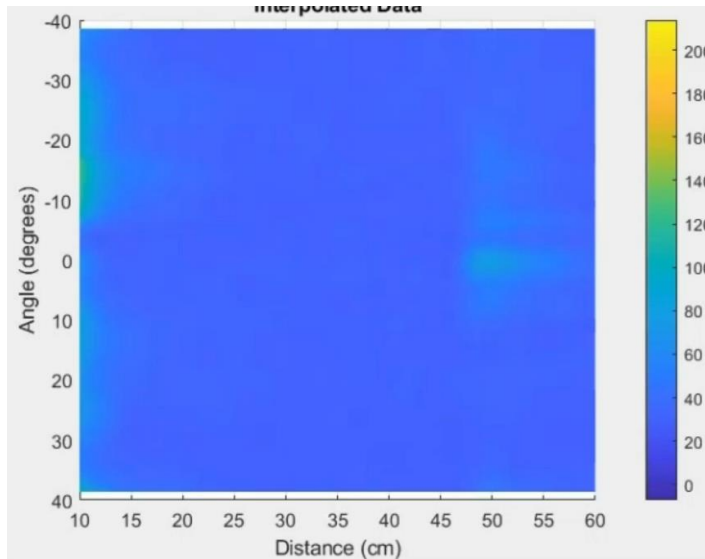
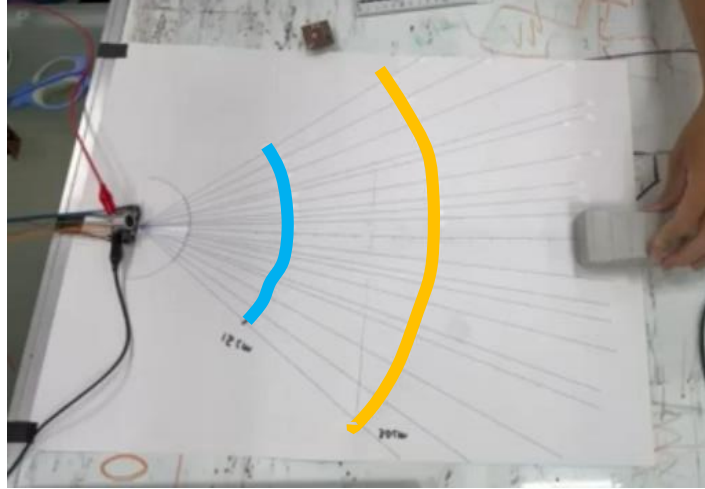


Experiment

15cm

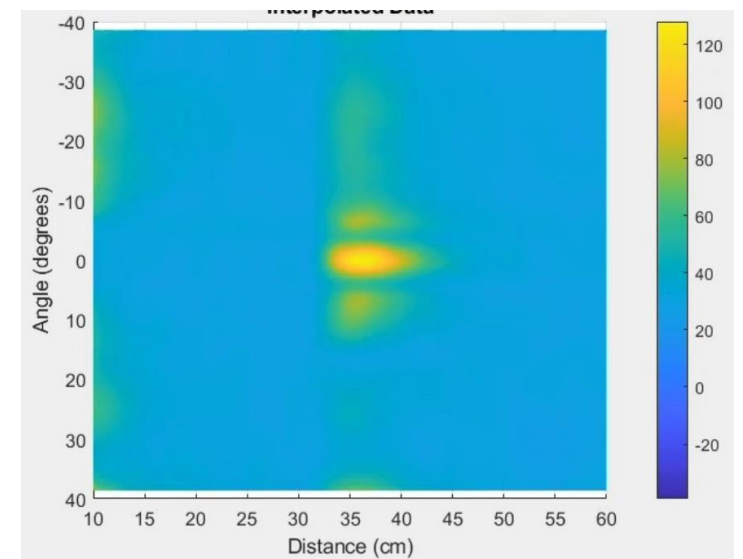
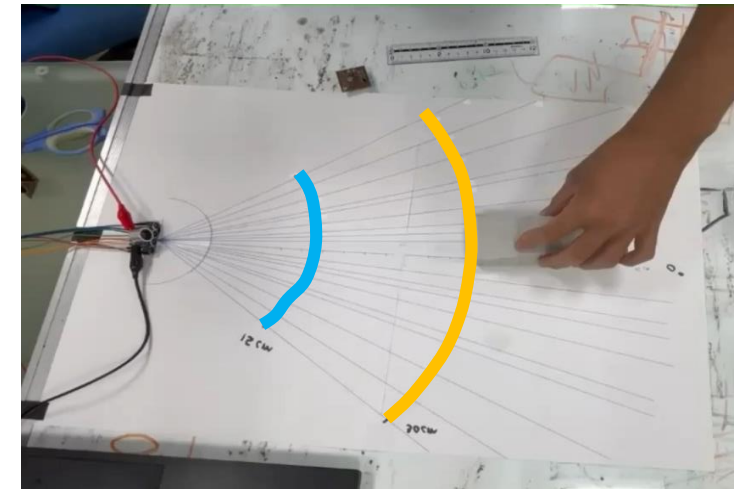
30cm

- Move the object at 1Hz
- Angle & distance

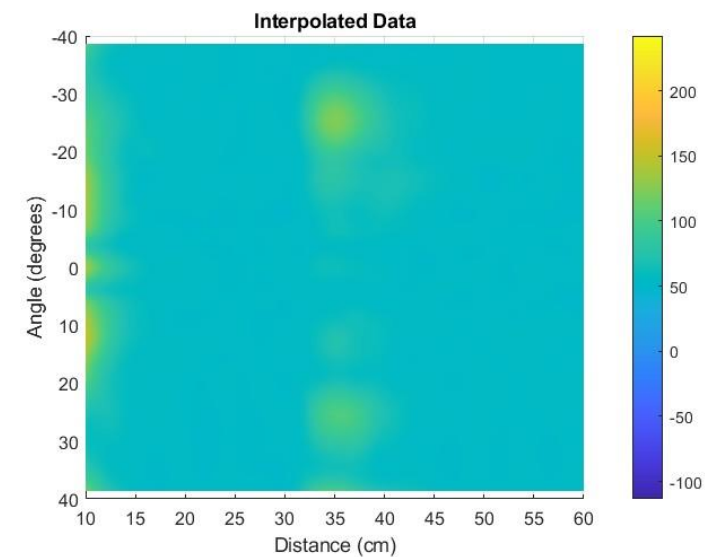
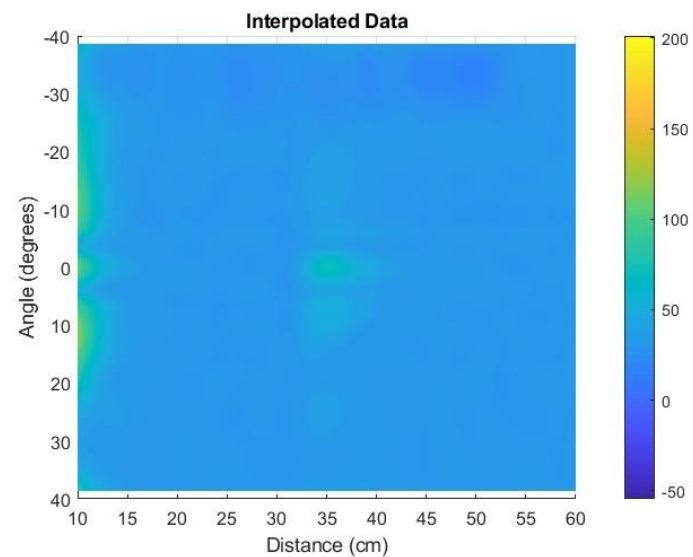
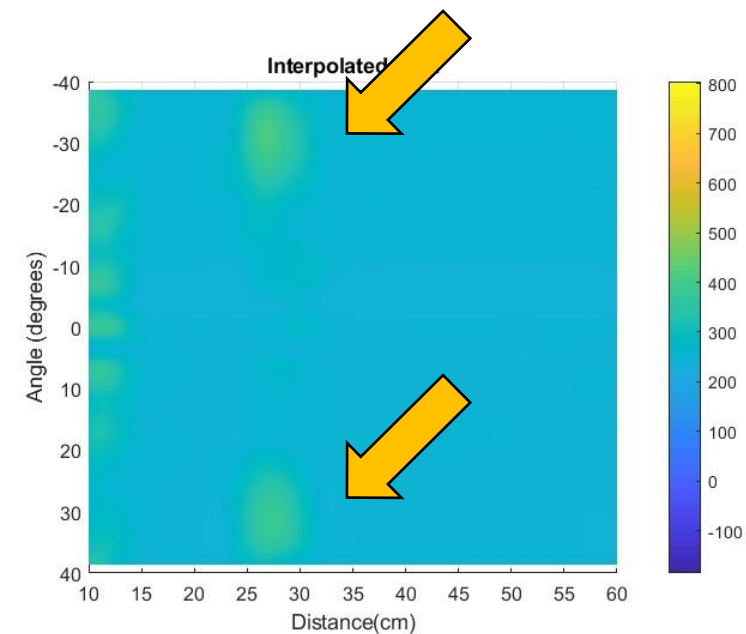
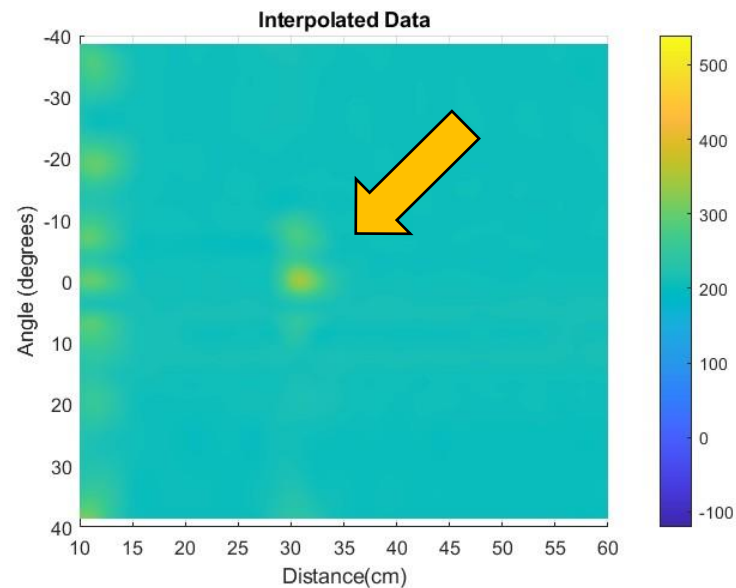
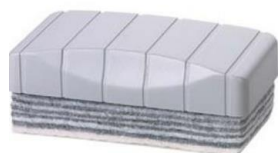


15cm

30cm



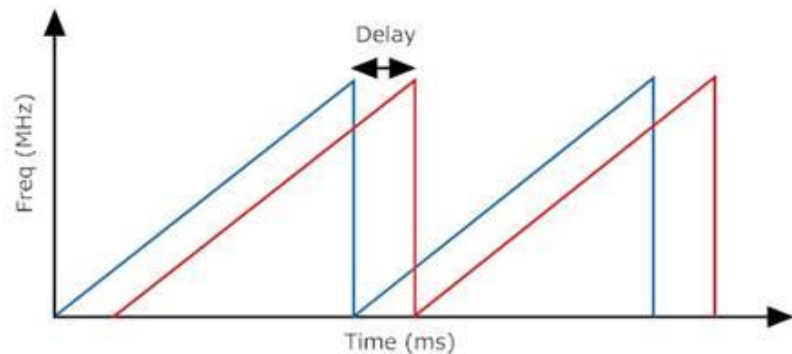
Imaging result



Conclusion

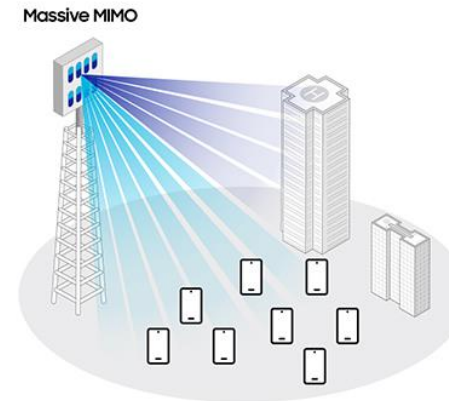
What we have done :

- ✓ Object Localization
- ✓ Grating lobe detection
- ✓ Off-line object imaging



Ultimate goal :

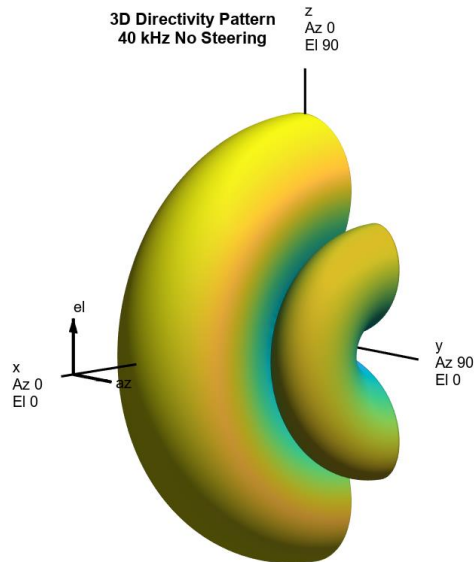
- ? Axial : 1mm Lateral : 0.05 radian
- ? Physiological signal monitor



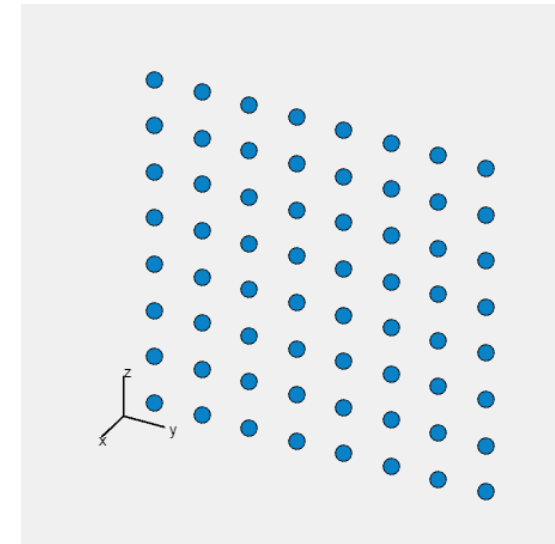
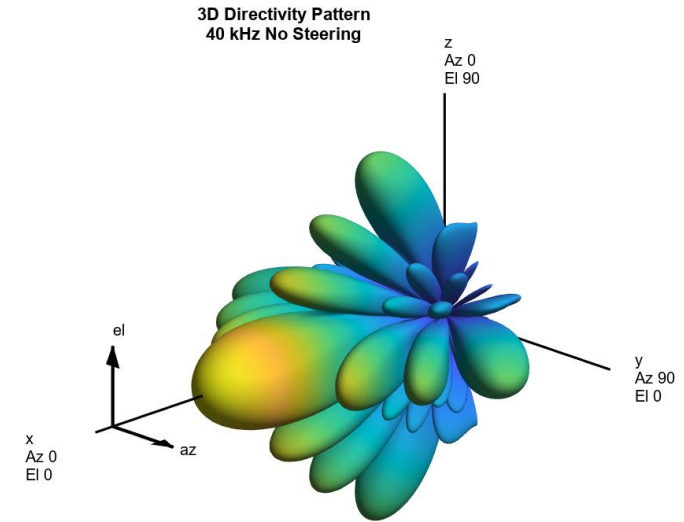
Future works

How do we improve:

✓ Axial : 1mm Lateral : 0.05 radian



Linear array 3D pattern

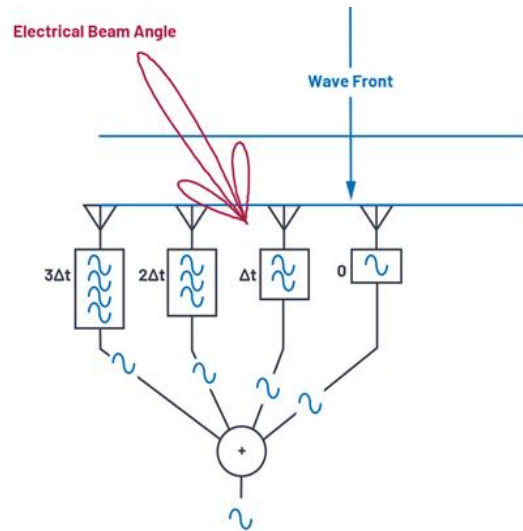


Multi-dimensional array geometry

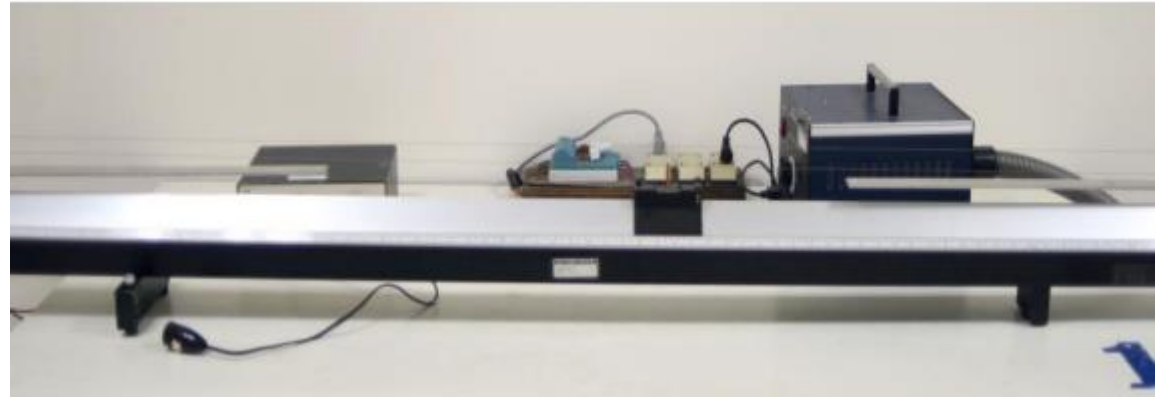
Future works

How do we improve:

- ✓ Physiological signal monitor

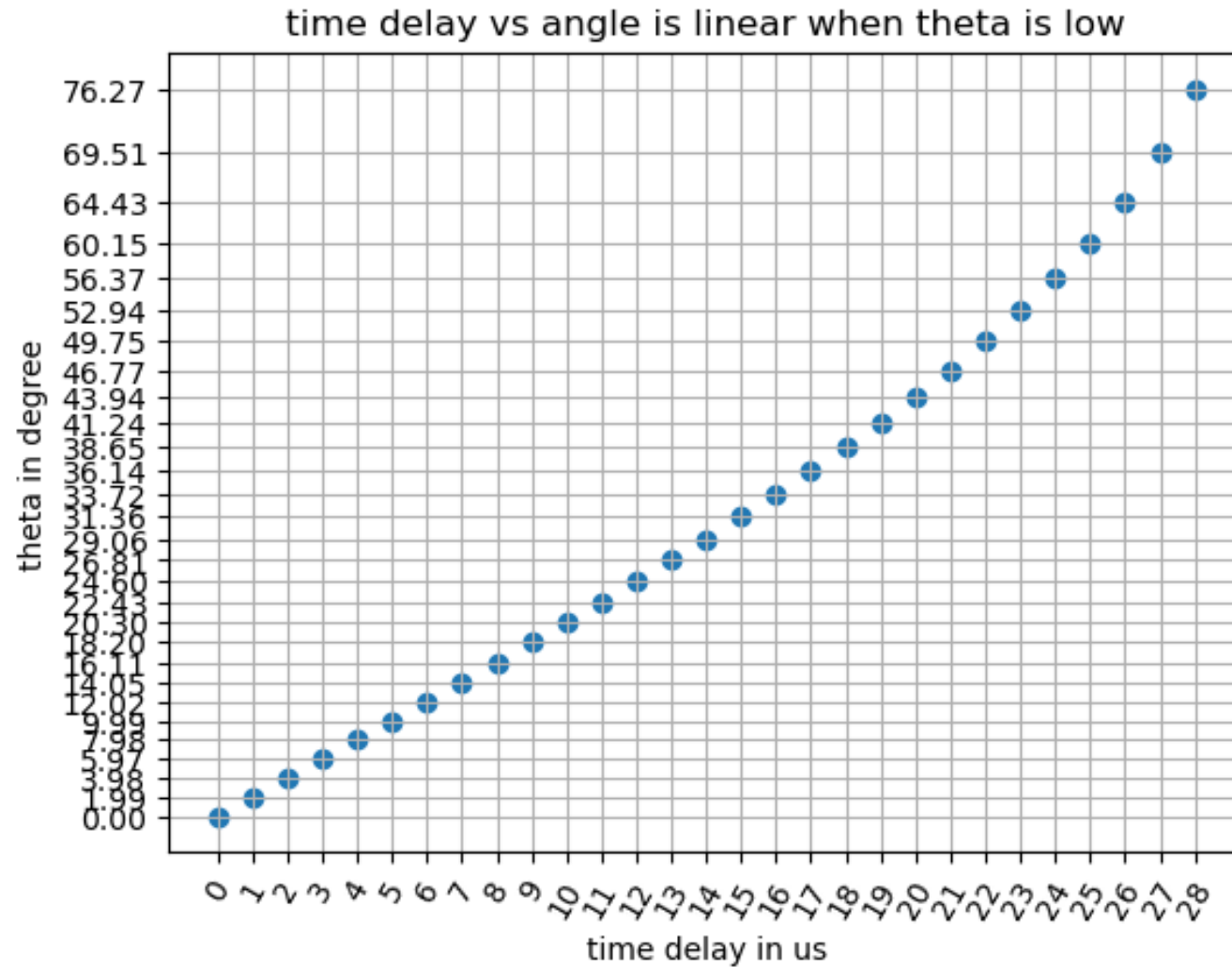


Receive-focused

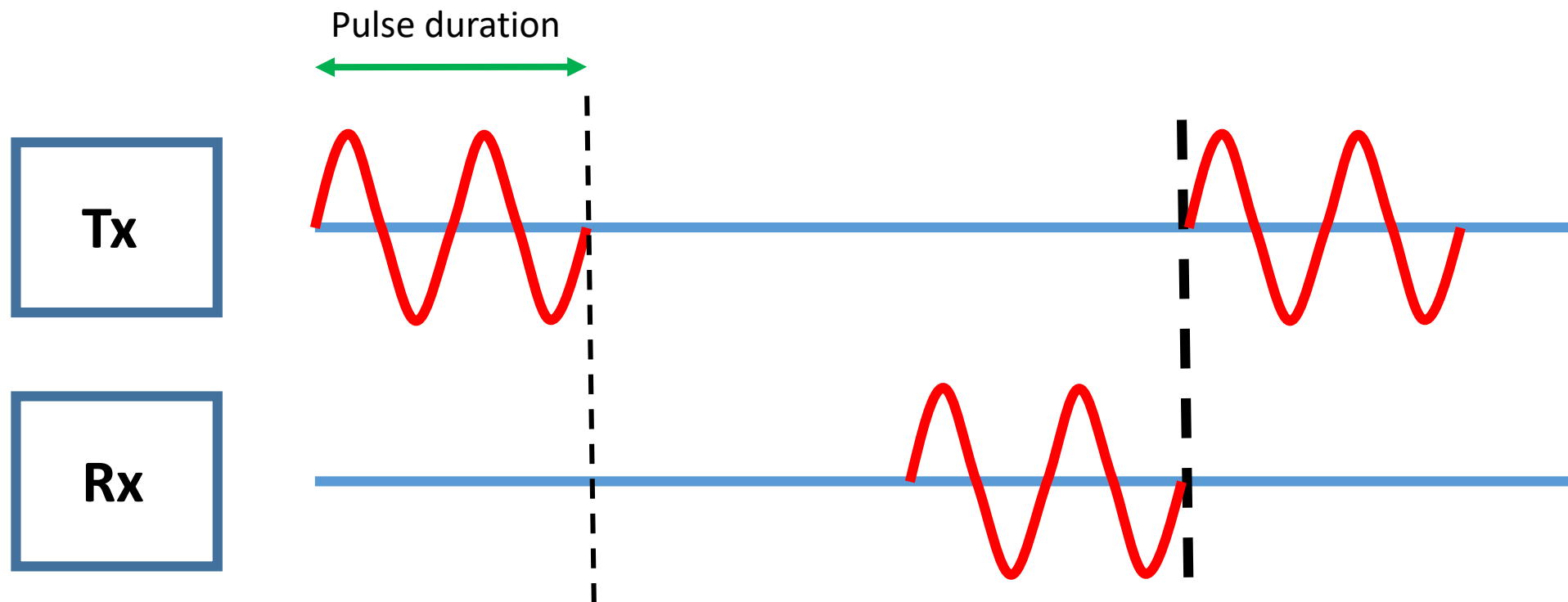


Simulate human breathing pattern with the slide rail

Rotation and steering angle



Pulse waveform (axial resolution)



Beam width(lateral resolution)

$$N = 4$$

$$d = 9.8 \text{ mm}$$

$$\lambda = 8.5 \text{ mm}$$

$$\theta_B \approx \frac{0.886 \cdot \lambda}{N d \cos \theta}$$

