Emerging trends in inCabin automotive sensing driving 3D Time-of-Flight innovation

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Workshop 2025
ePicture This
An initiative by PENTA/XECS label projects ENTERTAIN, IMAGINATION and ELEVATION supported by AENEAS

Organized by projects: 2021004 Imagination (Penta)
2023022 Elevation (Xecs)
2024001 Entertain (Xecs)

35

years Melexis

Melexis designs, develops, and delivers **edge sensor** and **driver solutions** with a **heart for people and planet**.

Long term growth trends

AUTOMOTIVE

- EV powertrain
- EV thermal management
- EV battery
- E-braking and e-steering
- Lighting

BEYOND AUTOMOTIVE

- Alternative mobility
- Sustainable world
- Robotics
- Digital health

20

years Triaxis®

+2000 **employees worldwide**

50% engineers

56 nationalities

34% women

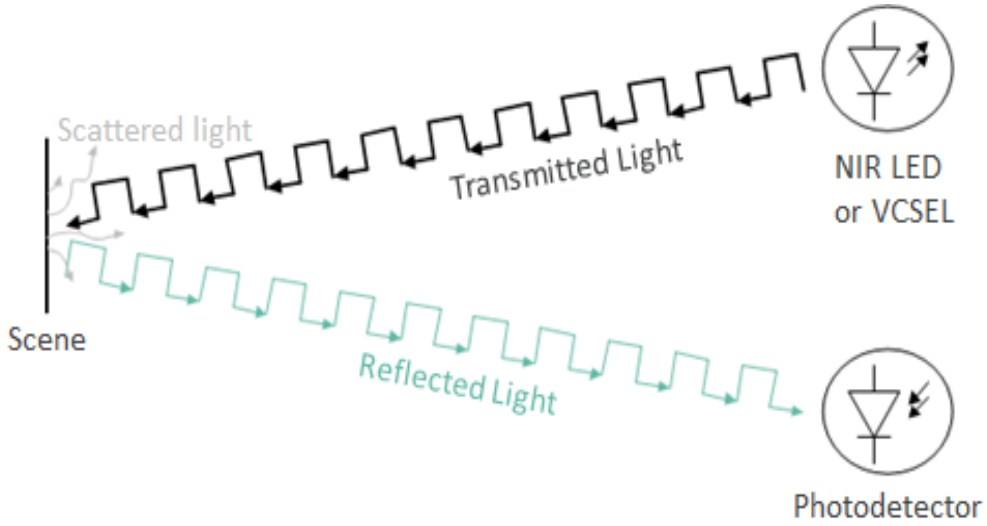
50/50

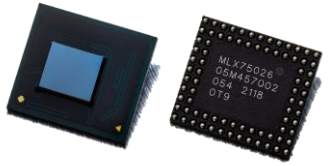
board of directors

Markets


Automotive
Alternative Mobility
Sustainable World
Robotics
Digital Health

- *ActiveLight proximity sensing*
- *Rain light sensors*
- *High dynamic range 2D ADAS sensor*
- *Far InfraRed products*
  - *Single pixel, 32x24 array*
- 3D Time of Flight camera solutions
  - QVGA, VGA

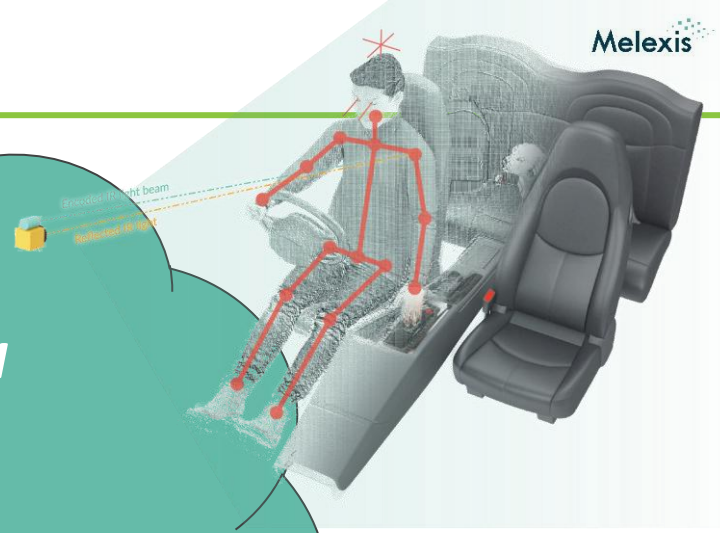




NHTSA

EURO NCAP

InCabin Application Space



HMI/UX
Gesture control

Occupant Monitor System (OMS)
Comfort functions
FaceID

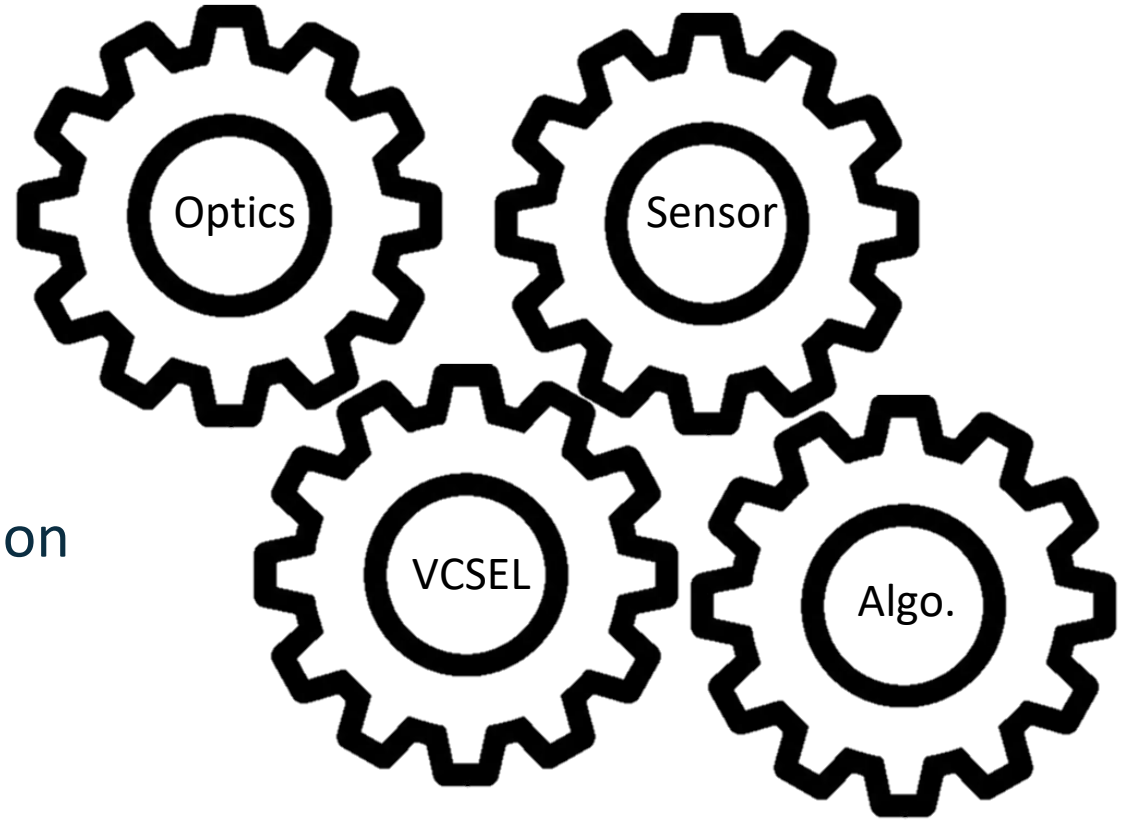
"Intelligent Interior" Camera
Driver Monitoring
Hands on & seatbelt detection
Occupant presence & classification
Smart Restraint Control System or
Dynamic Airbag Supp. System
Personal seat & mirror positioning
Secure FaceID
Performant gesture control
Adaptive (interior) lighting

2017 — 2025 — 2029

Wider FOV, longer distance, more robust, …
Market push towards sensor oriented companies for module level involvement
Imagination enabler of exploration competencies at system level

Longer Range

Unambiguous Range Extension



Robust

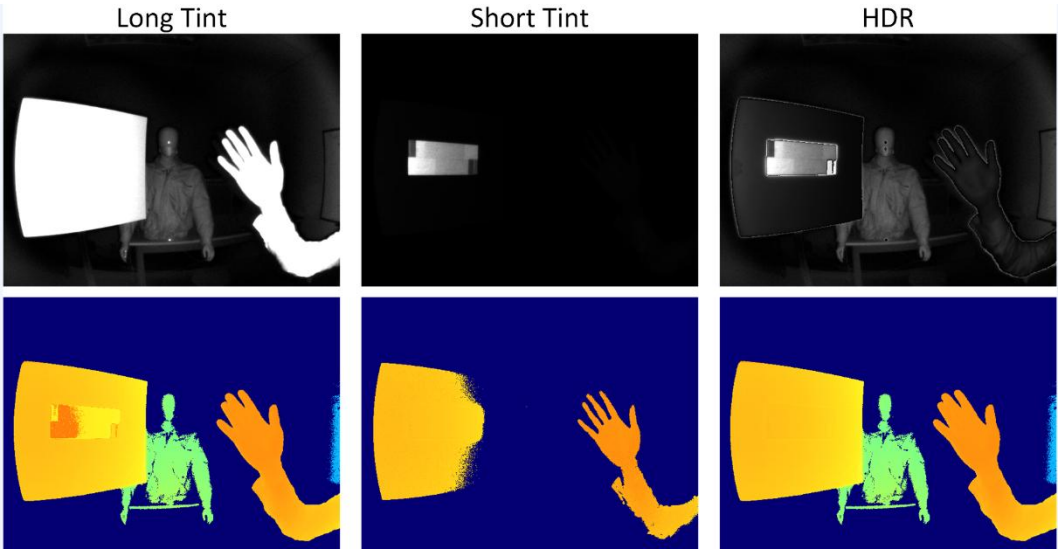
Multi-path Mitigation

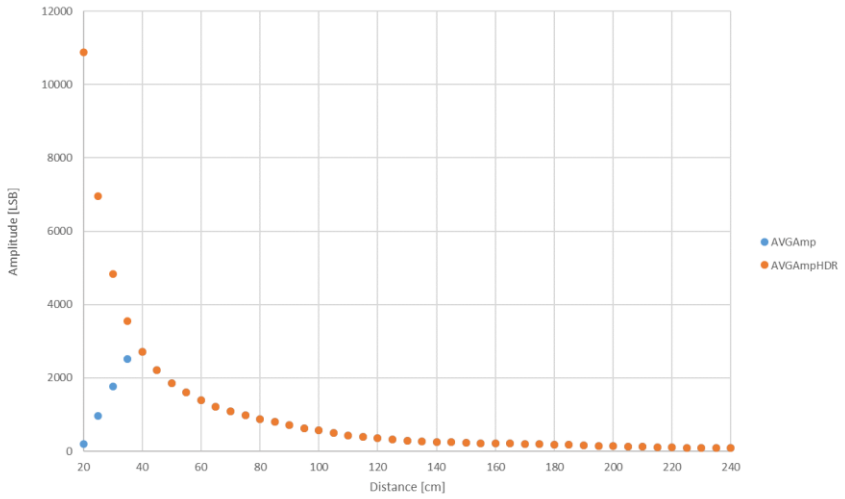
Wider FoV

Multi-exposure

Auto-exposure

Multi- Exposure





Multi-exposure:

- **Detect both bright & dark objects**
- Integration time: Long Short
  - Objects distance: far close
  - Objects reflectance: low high

- 2D: market mature feature
  - Multi-exposure@ sensor level
- ToF: 2D & 3D data
  - Multi-exposure@ system level

If(Long_SaturationFlag == False)

Amplitude_HDR = Amplitude_LongTint

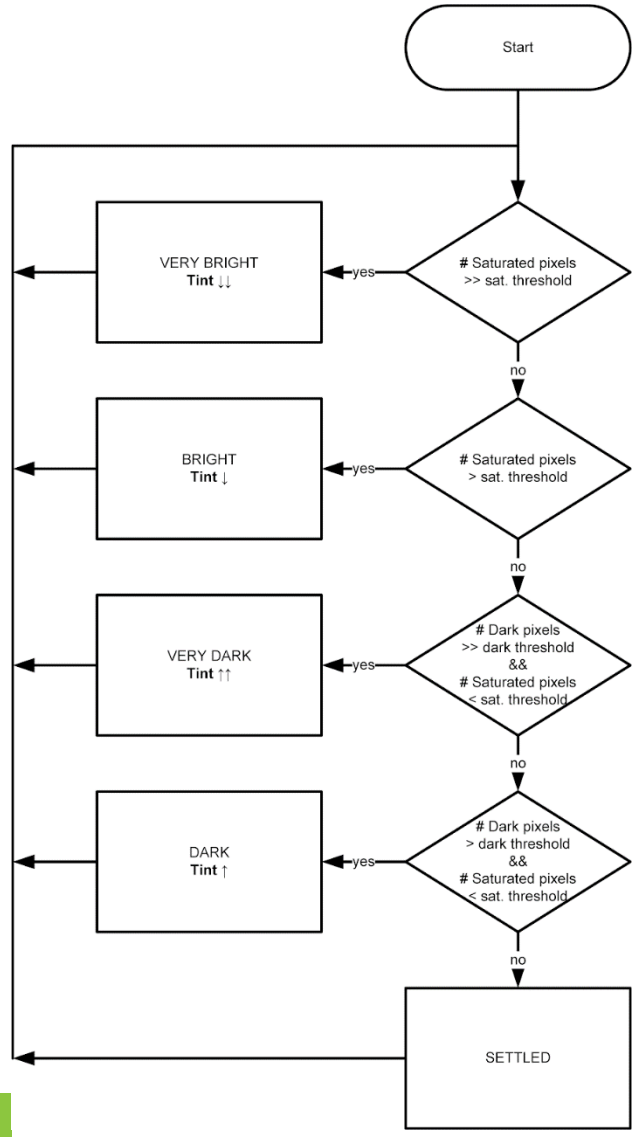
Distance_HDR = Distance_LongTint

Else

Amplitude_HDR = Amplitude_ShortTint(LongTint/ShortTint)*

Distance_HDR = Distance_ShortTint

Auto-Exposure

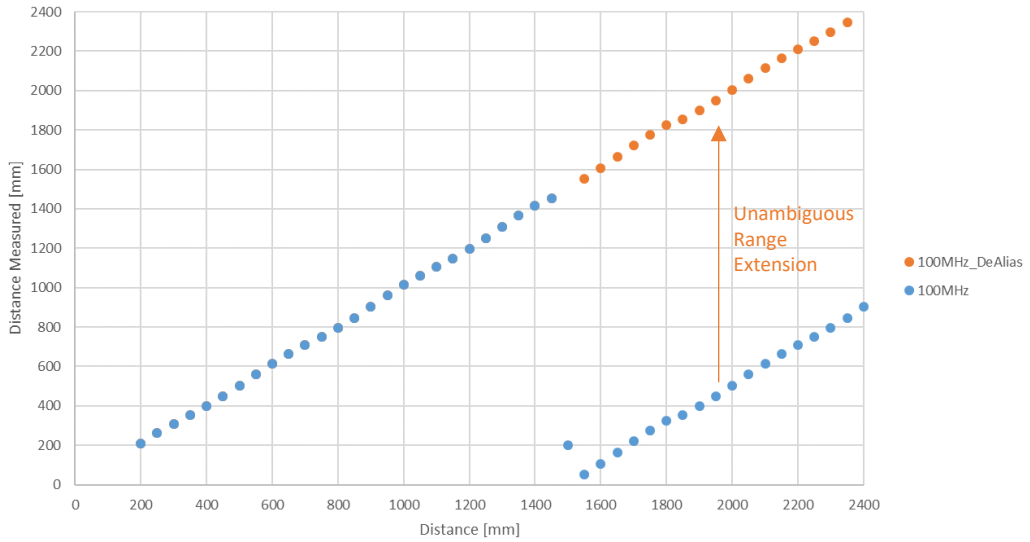


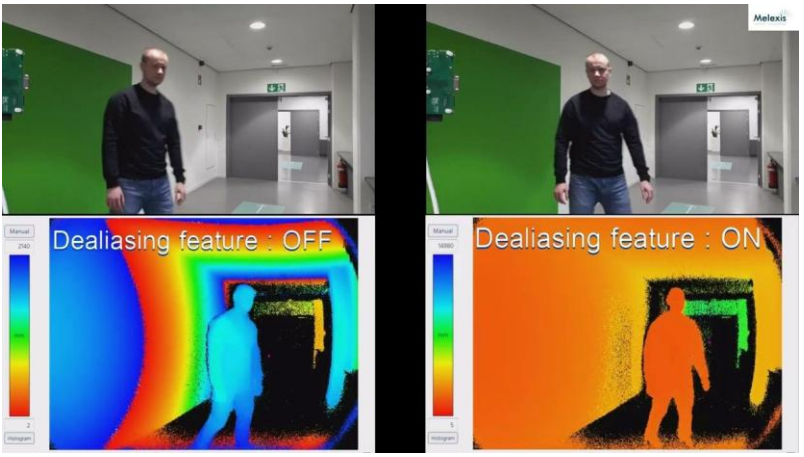
Auto-exposure:

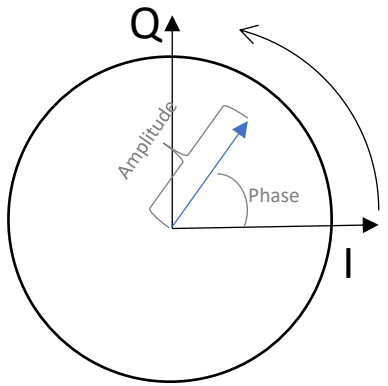
- **Lowest noise under all circumstances**
- ToF: Distance noise proportional to integration time
  → best case integration time under all circumstances

- <u>BUT</u> optimal integration time = scene dependent
  - Too low = noisy
  - Too high =saturation
- State machine @ system level
  - Use information from previous frames
    - #Dark pixels (pixels < amplitude threshold)
    - #Saturated pixels
  - Update integration time

Unambiguous Range Extension







ToF fundamental operating principle:

- Emit wave at modulation frequency
- Measure phase shift vs. returning wave
- Convert phase shift to distance

Limitation:

- Phase measured between 0-360 degrees → limited range
- Distance noise proportional to modulation frequency

Practical example 100MHz:

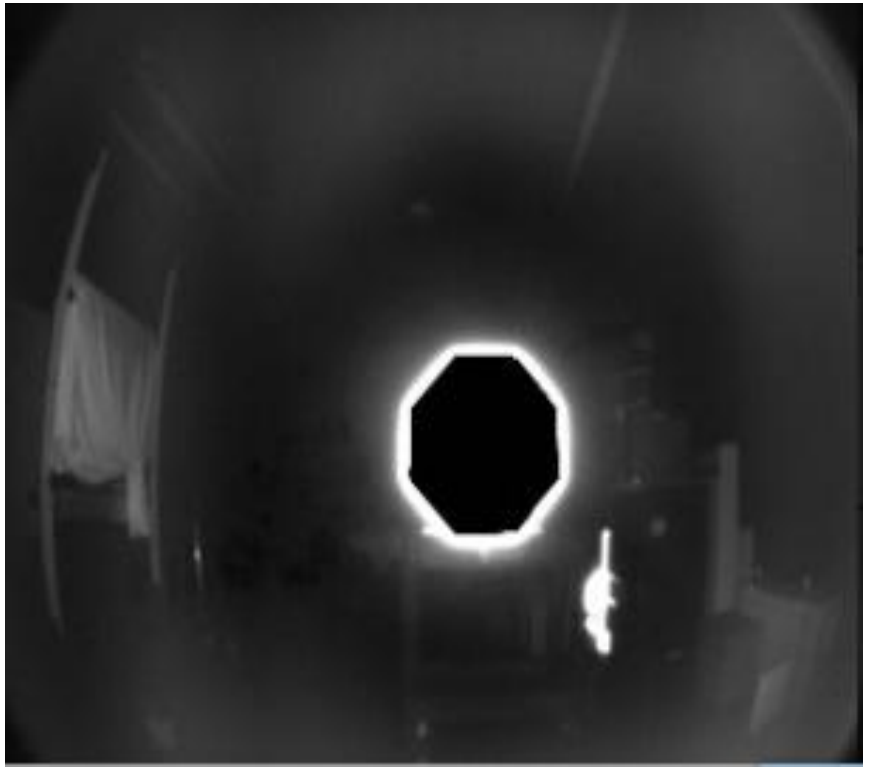
45deg = 187mm, 360deg = 1500mm, 405deg = ~~360deg~~+45deg = 187mm

Unambiguous range extension:

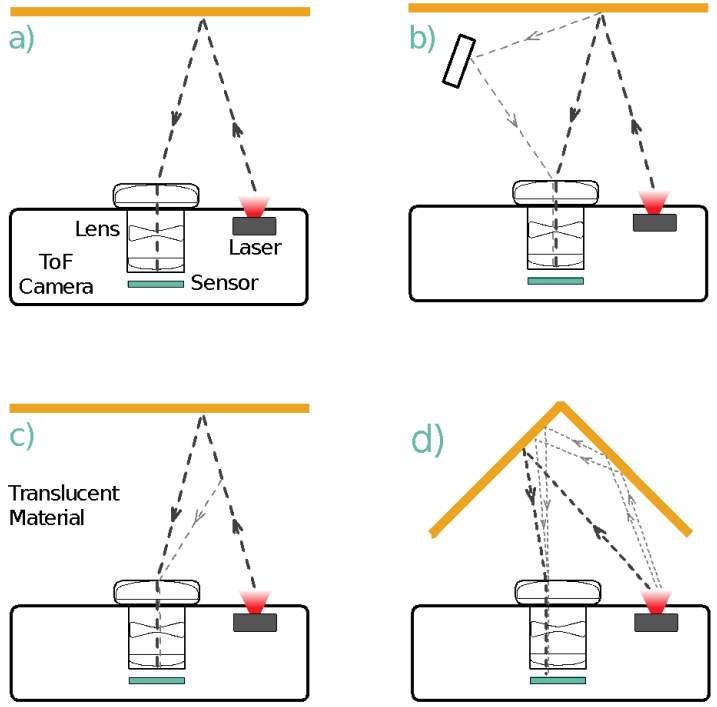
Achieve high range and high precision

- Combination of two measured frames at different frequencies
- Achieve noise of highest frequency, range of frequency difference

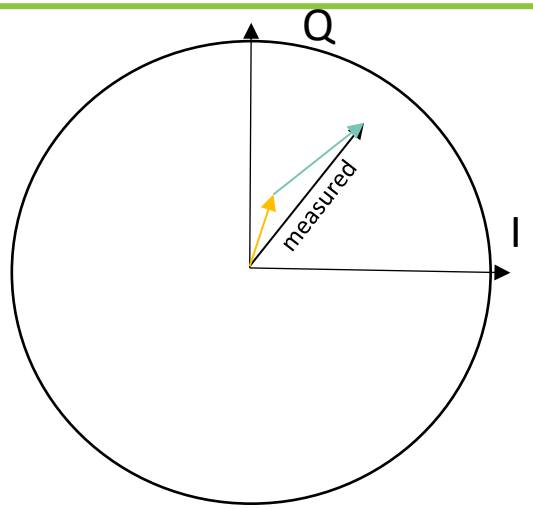
Internal Multipath (lens flare)

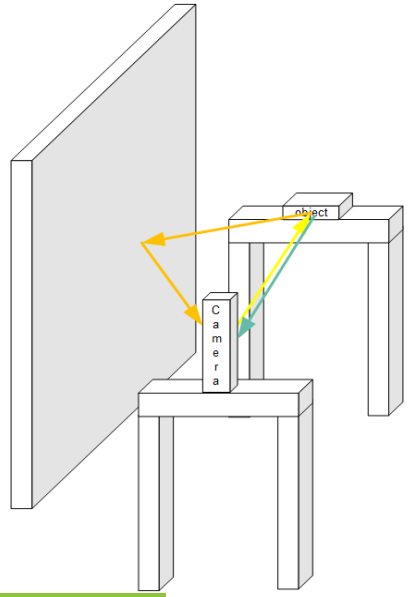


External Multipath



Multi-path Mitigation

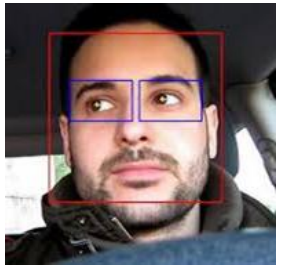




Each meas. vector [Amplitude, Phase]
= true vector & potential multipath vector component

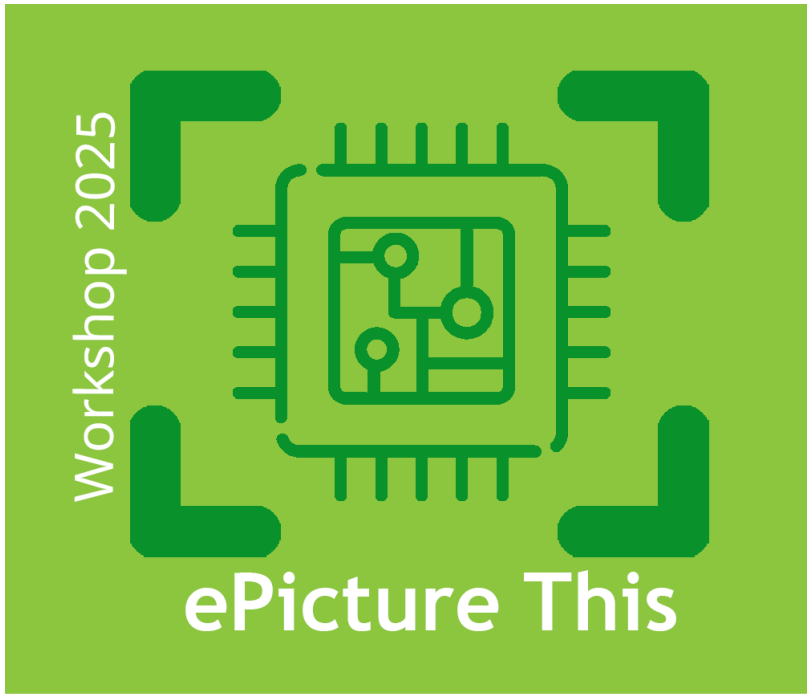
Multi-path Mitigation:
Filter out any influence caused by unwanted reflections

- Two measurement frames at different frequencies
- FMOD2 = 2*FMOD1
- Calculate:
  - PhaseDiff = ϕ2-2*ϕ1
  - AmpRatio=Amp2/Amp1
- Use the relationship (PhaseDiff and AmpRatio) to determine the following vectors per frame:
  - Phase: Shortest longest
  - Amplitude: Brightest darkest
- Post process based on brightness/Phase to get the right vector component



Multi-exposure
Auto-exposure
Unambiguous Range Extension
Multi-path Mitigation

By introducing features like: unambiguous range extension, HDR, auto-exposure and MPI, driven by automotive requirements, the system level's performance is taken to the next level opening the door to new application spaces beyond automotive.



THANK YOU

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