WE1D-2

A Fully 3D-Printed Flexible Millimeter-Wave Doppler Radar

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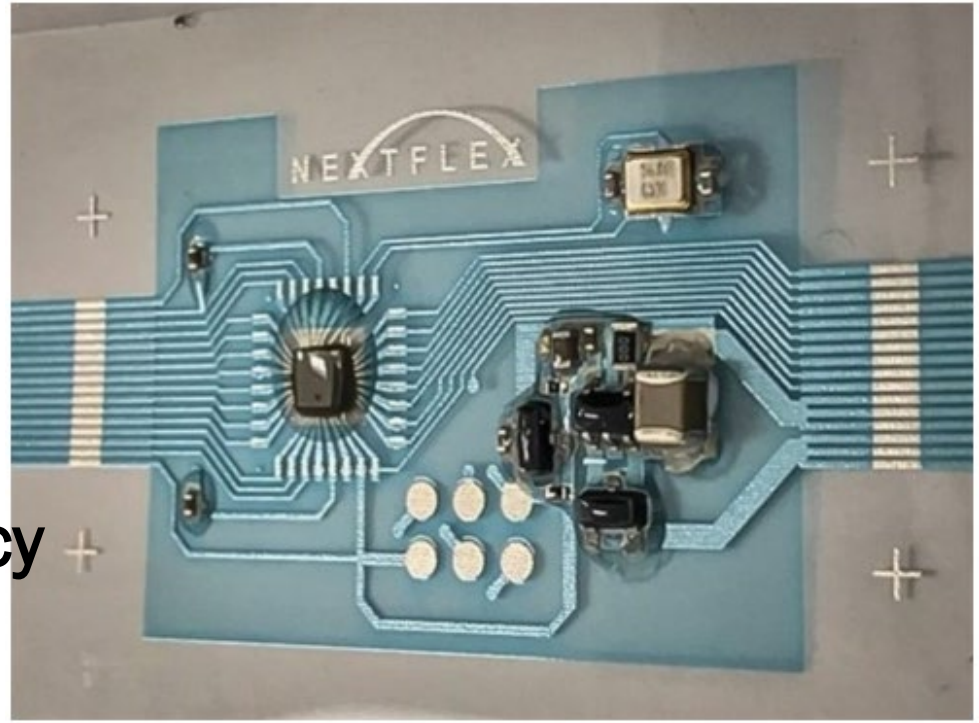
Outline

- Introductions to flexible hybrid electronics
- 3D-printed Doppler radar design
  - Design diagram
  - Layer stack-up
- Printing processes
- Radar characterization
  - Antenna arrays
  - Field tests for the printed mmWave radar
- Conclusions

Introductions to flexible hybrid electronics

- Flexible hybrid electronics (FHE)
  - Flexible
  - Hybrid technology
  - Thin and lightweight
  - Customizable
  - Limited performance → Two layers
  - Low design complexity → Low frequency
- Key Challenges
  - Proper printing materials
  - Reliable bonding layers
  - Robust interconnections

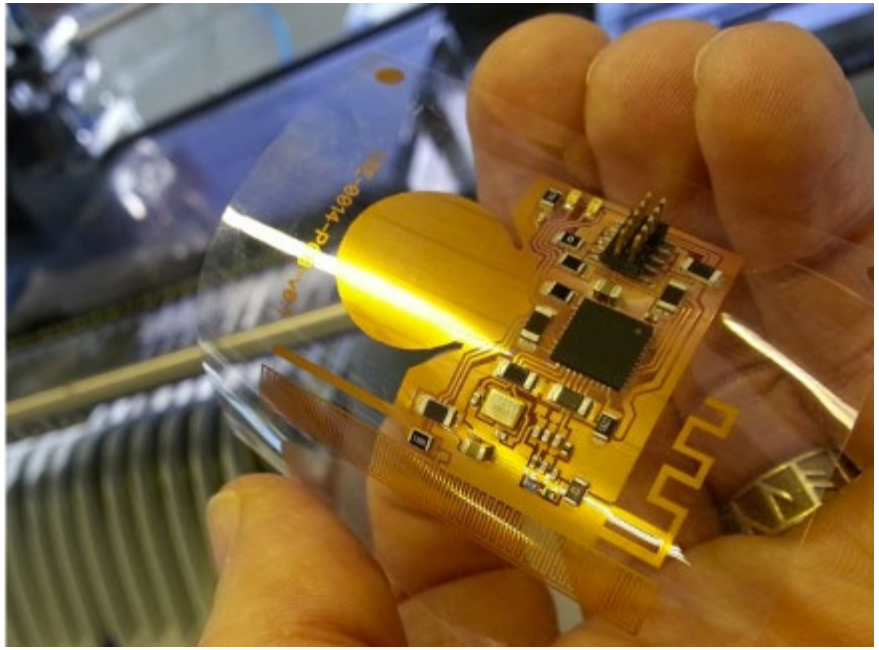


3D-printed FHE circuits[1]

[1] https://www.designhmi.com/2016/07/26/flexible-hybrid-electronics/

3D-printed flexible Doppler radar design

- Key challenges
  - Proper printing materials
  - Reliable bonding layers
  - Robust interconnections
- Our solutions
  - A combo of commercial PCB and TPC
  - High heat flexible epoxy
  - Mechanically drilled vias filled with epoxy

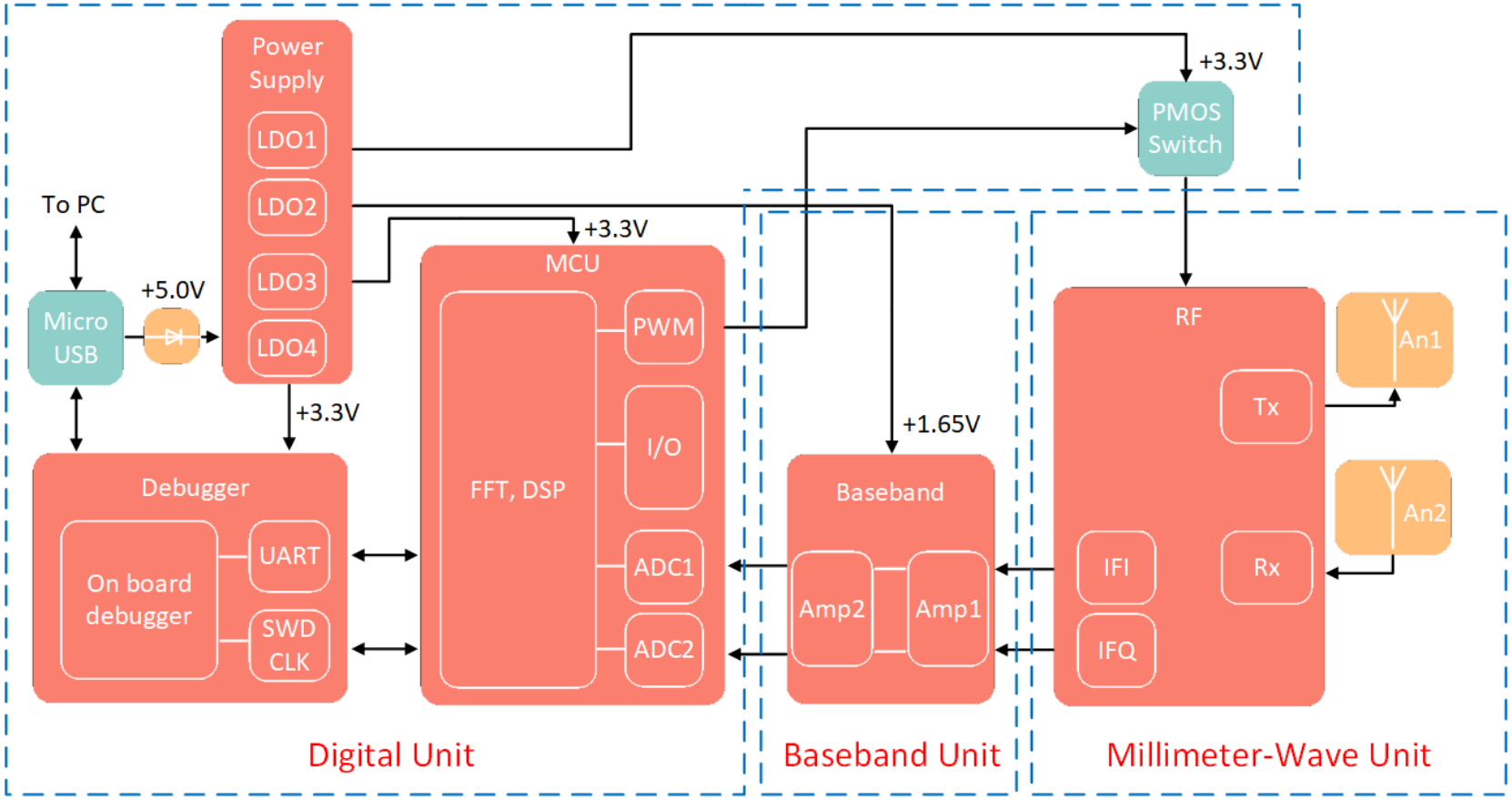


3D-printed FHE circuits[2]

https://www.designhmi.com/2016/07/26/flexible-hybrid-electronics/

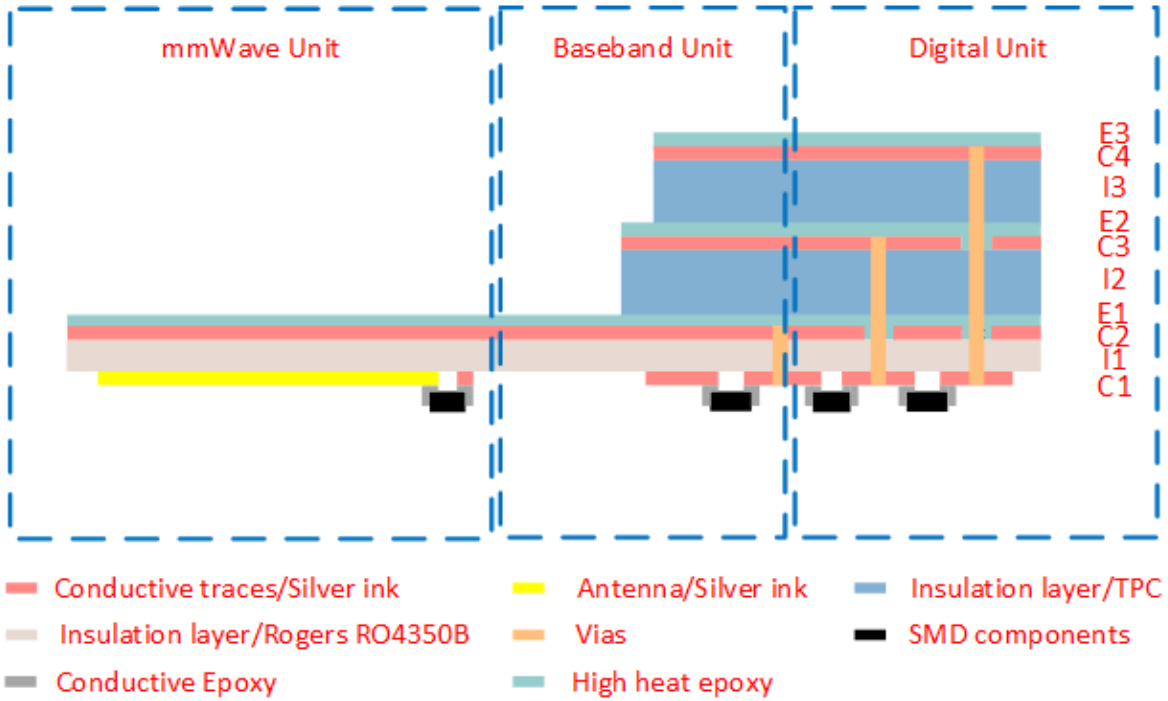
3D-printed flexible Doppler radar design

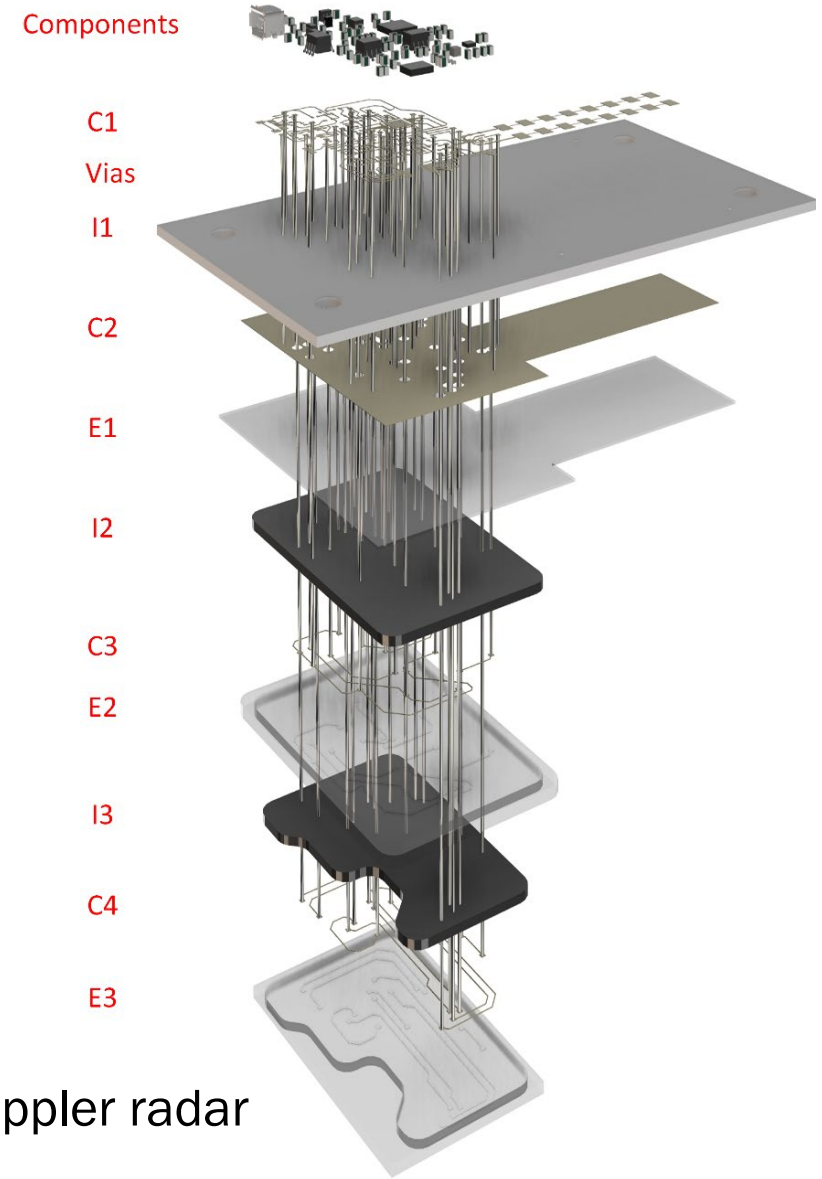
- Diagram
  - Digital unit
  - Baseband unit
  - mmWave unit



The design diagram of the proposed Doppler radar

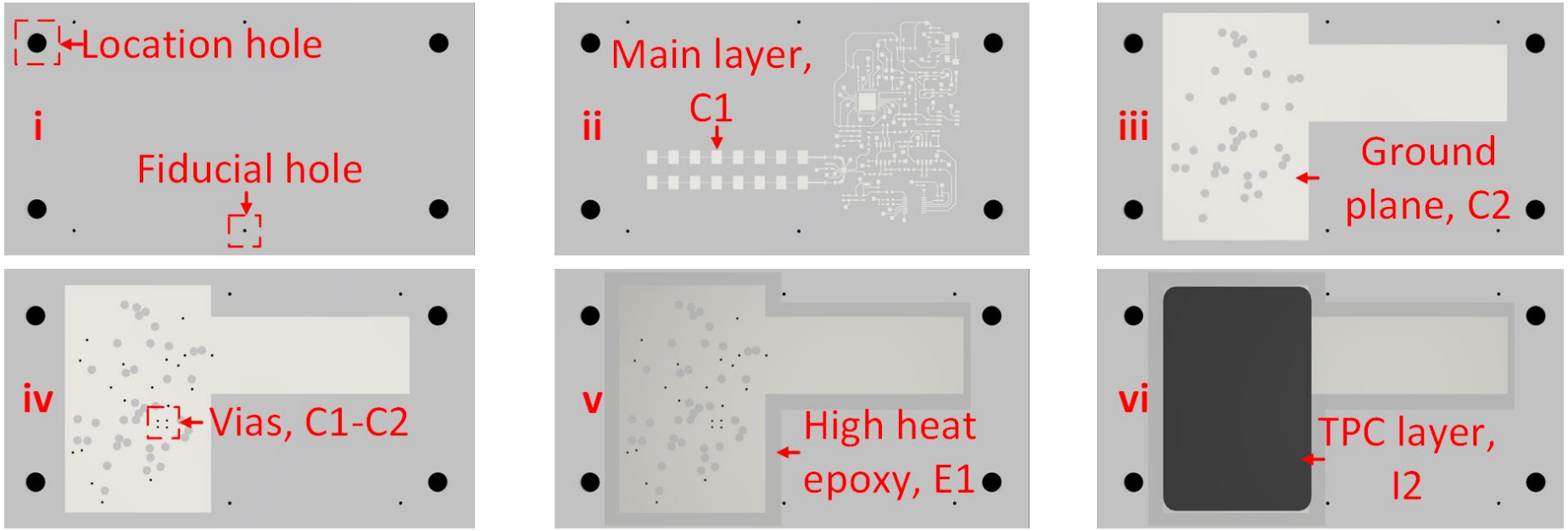
Layer stack-up





The layer stack-up of the proposed 3D Doppler radar

Printing processes

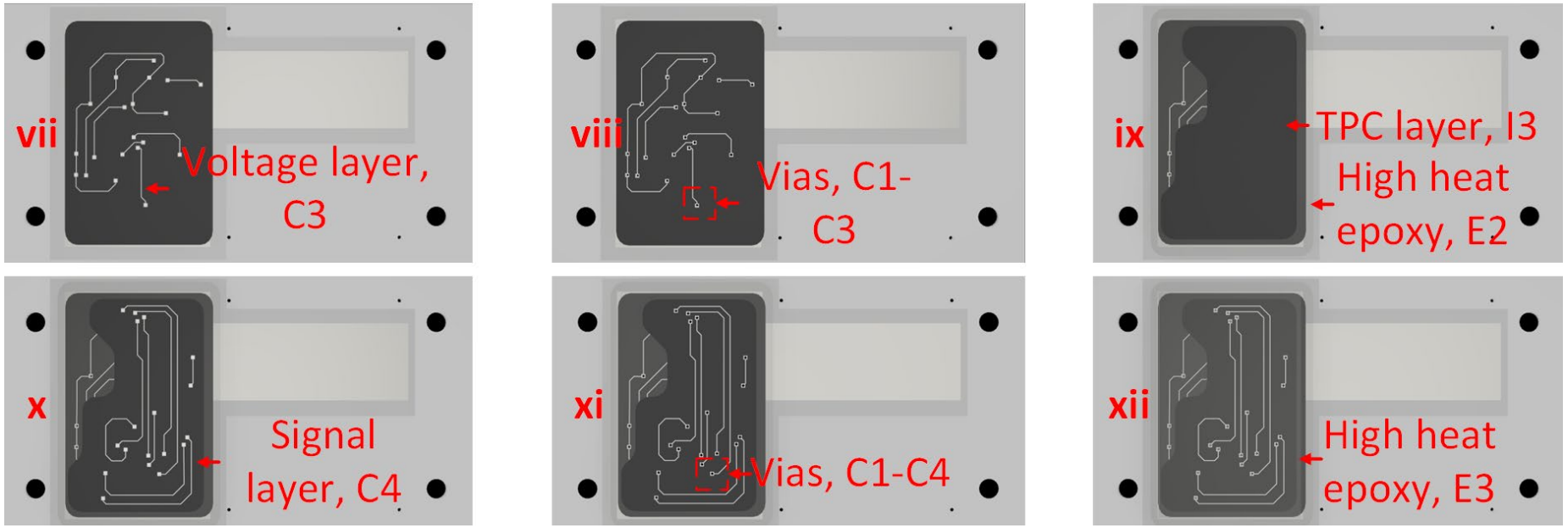


Printing processes

Drill fiducial holes → Print first layer(C1) → Print ground layer(C2)

Drill C1-C2 vias → Coat high heat epoxy(E1) → Print first TPC layer(I2)

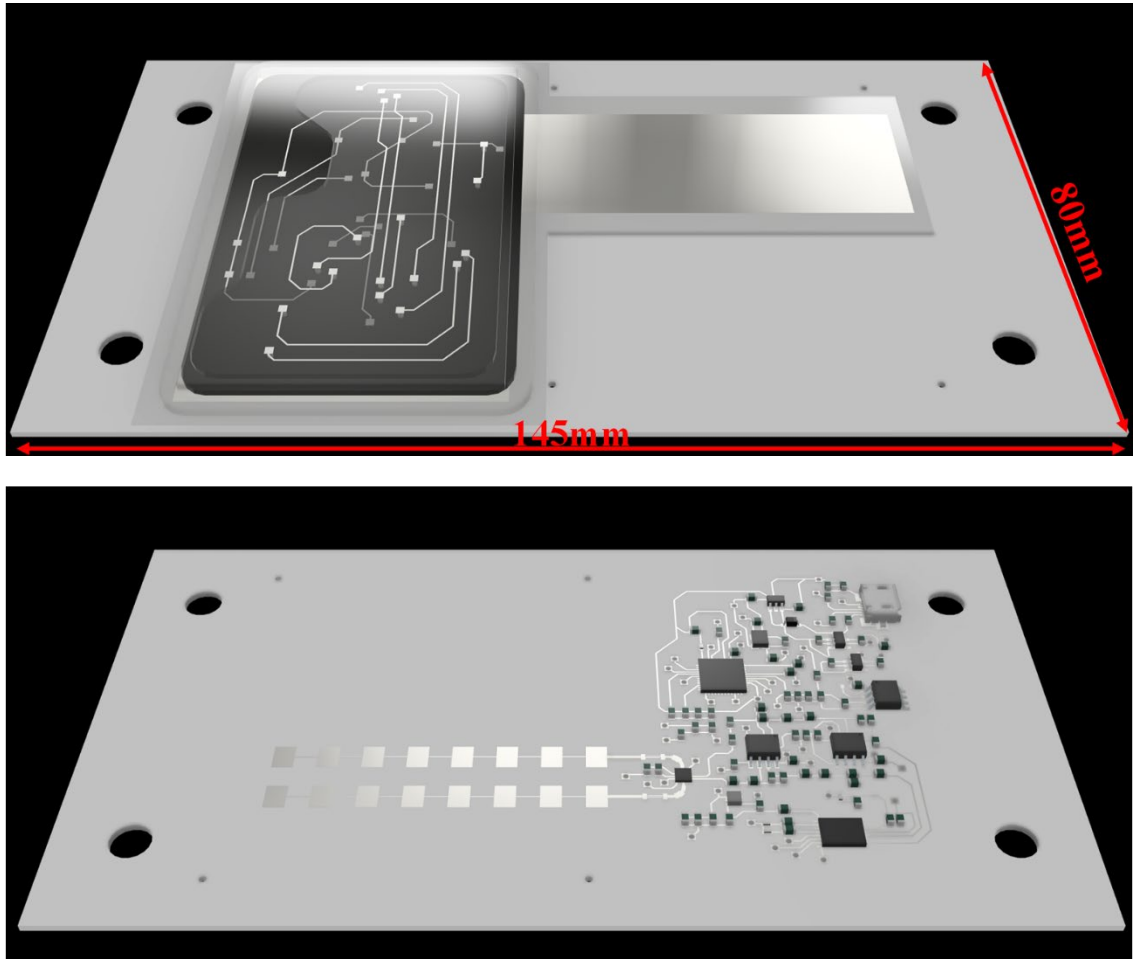
Printing processes

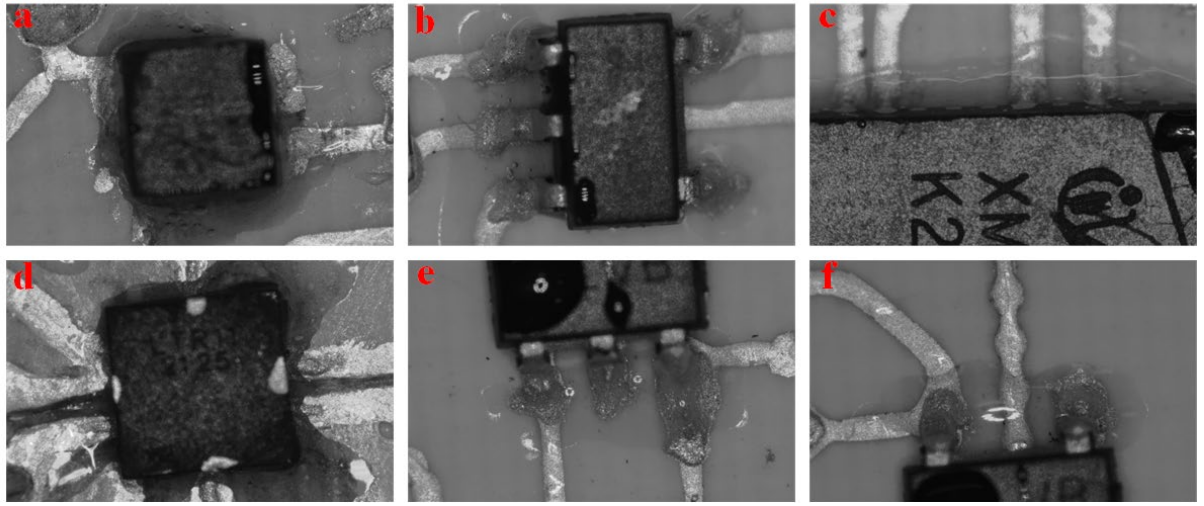


Printing processes

Print voltage layer(C3) → Drill vias(C1-C3) → Coat epoxy(E2) and print TPC layer(I3)
Print signal layer(C4) → Drill vias(C1-C4) → Coat epoxy(E3)

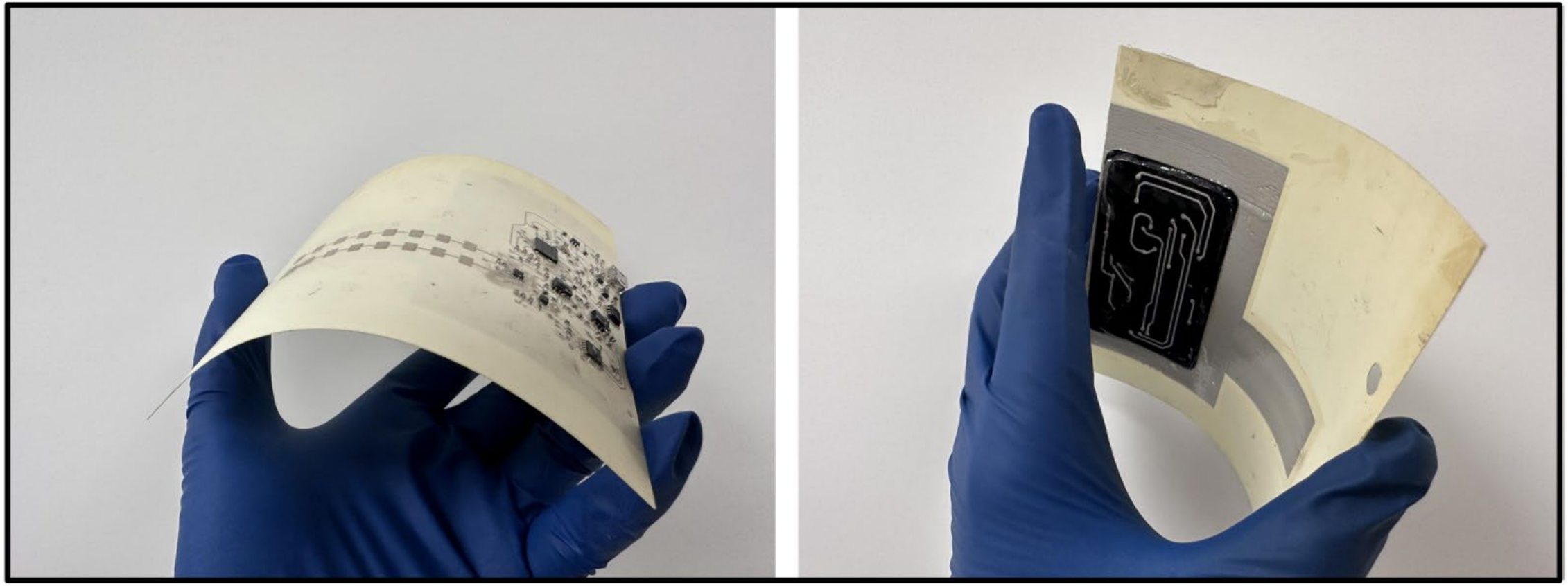
Printing processes





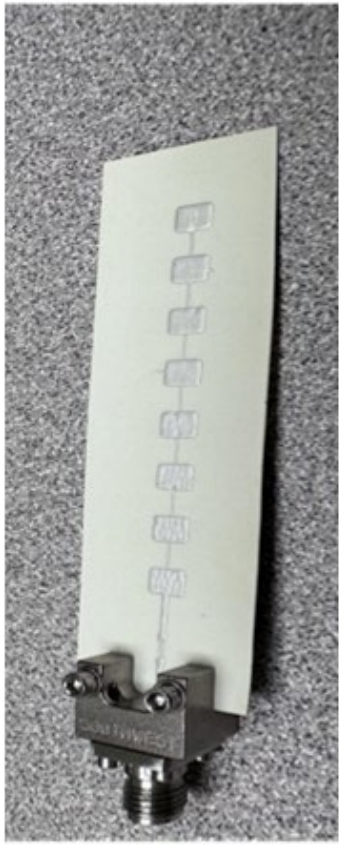
Assemble the components on the printed board by conductive epoxy and high-heat epoxy

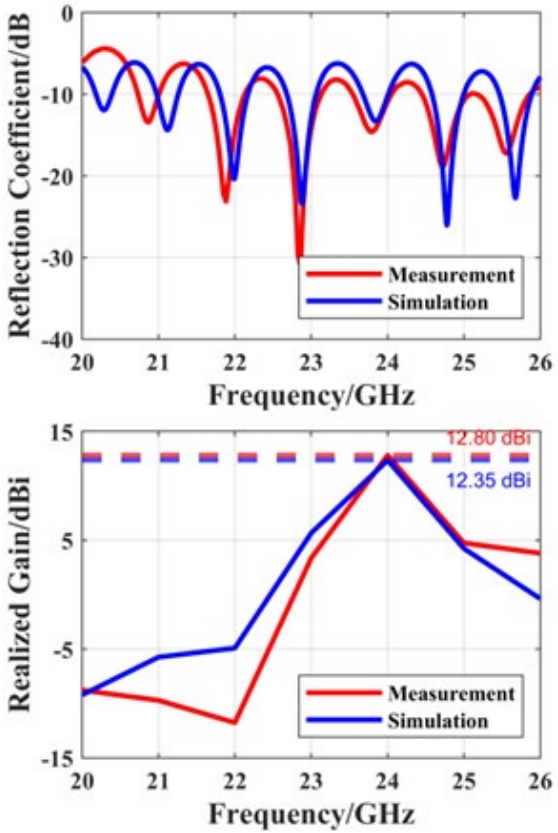
Radar characterization



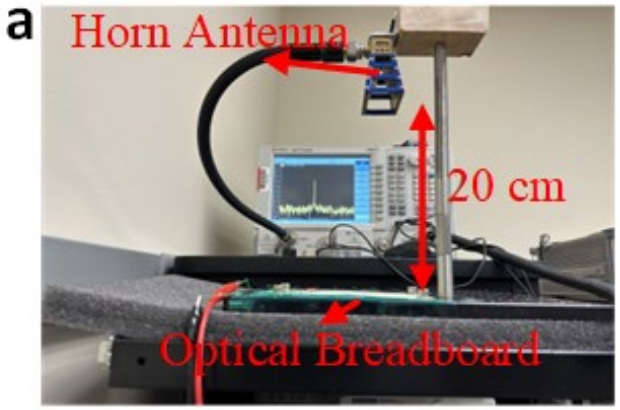
Photos of the 3D-printed flexible mmWave radar

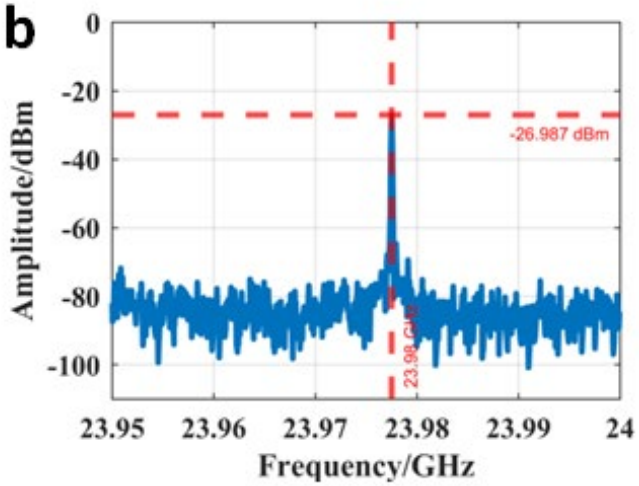
Radar characterization





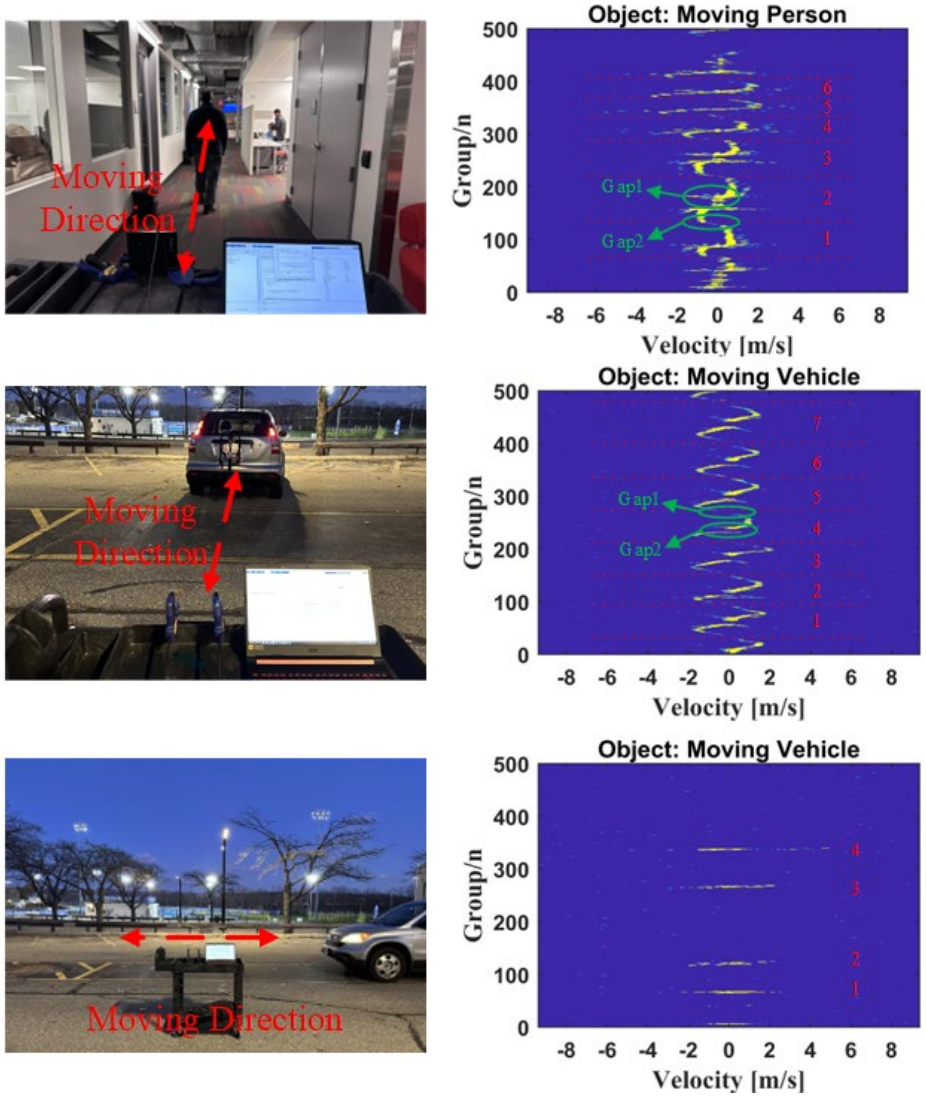
Printed 24 GHz antenna array calibration





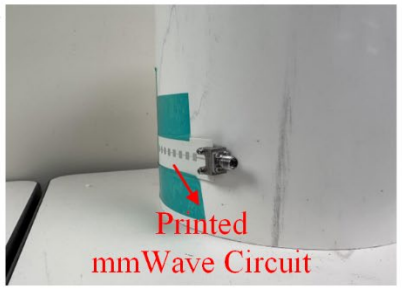
Radar spectrum measurement

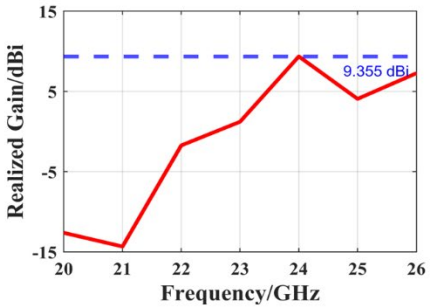
Radar characterization-field tests

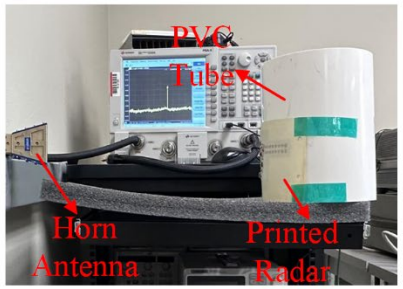


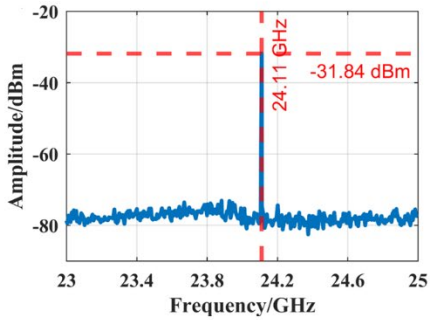
Field tests for the printed flexible mmWave radar

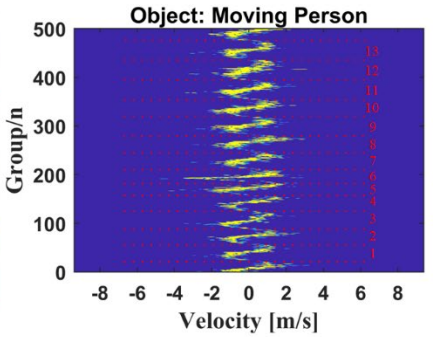
Radar characterization-flexibility tests







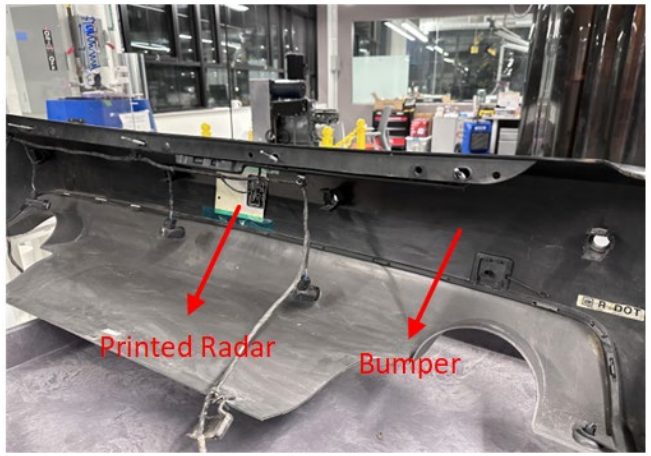


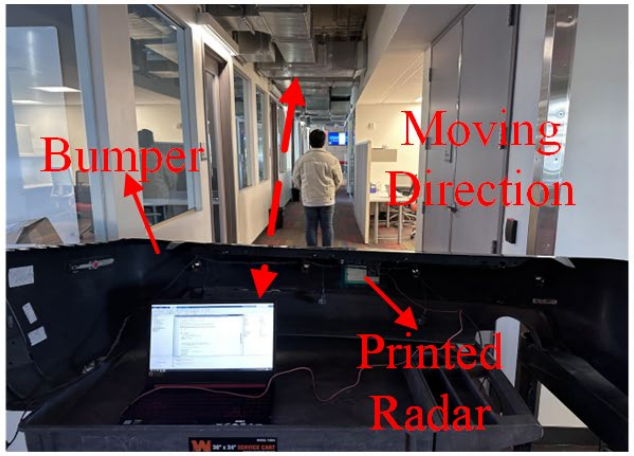


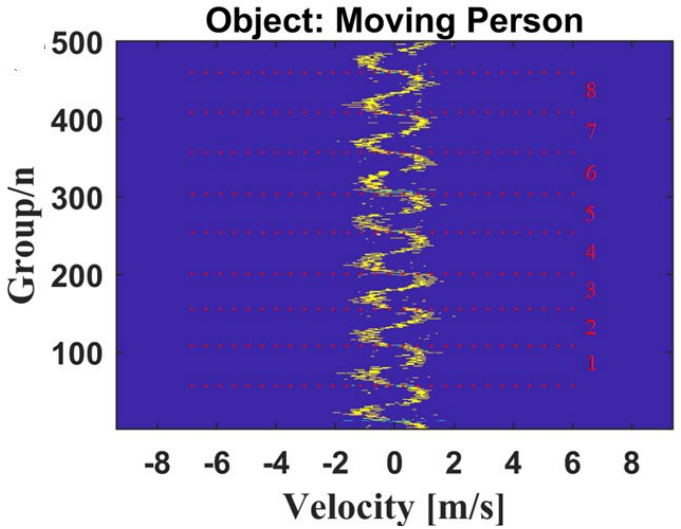
Flexibility tests for the printed flexible mmWave radar

Radar characterization-flexibility tests

The proposed 3D-printed radar was attached to a vehicle's rear bumper cover by tapes.







Flexibility tests for the printed flexible mmWave radar

Conclusions

- Our achievements
  - We developed a 3D-printed multilayer flexible mmWave Doppler radar.
  - The detection performance and flexibility of the prosed radar have been characterized.

- Challenges and future plans
  - Commercial PCB substrate?
  - Mechanically drilled and manually filled vias? → Calibrate the TPC
  - Blade-coated high-heat epoxy? → One-part epoxy
  - Components assembly? → Design adapters or anisotropic epoxies