

We1D-1

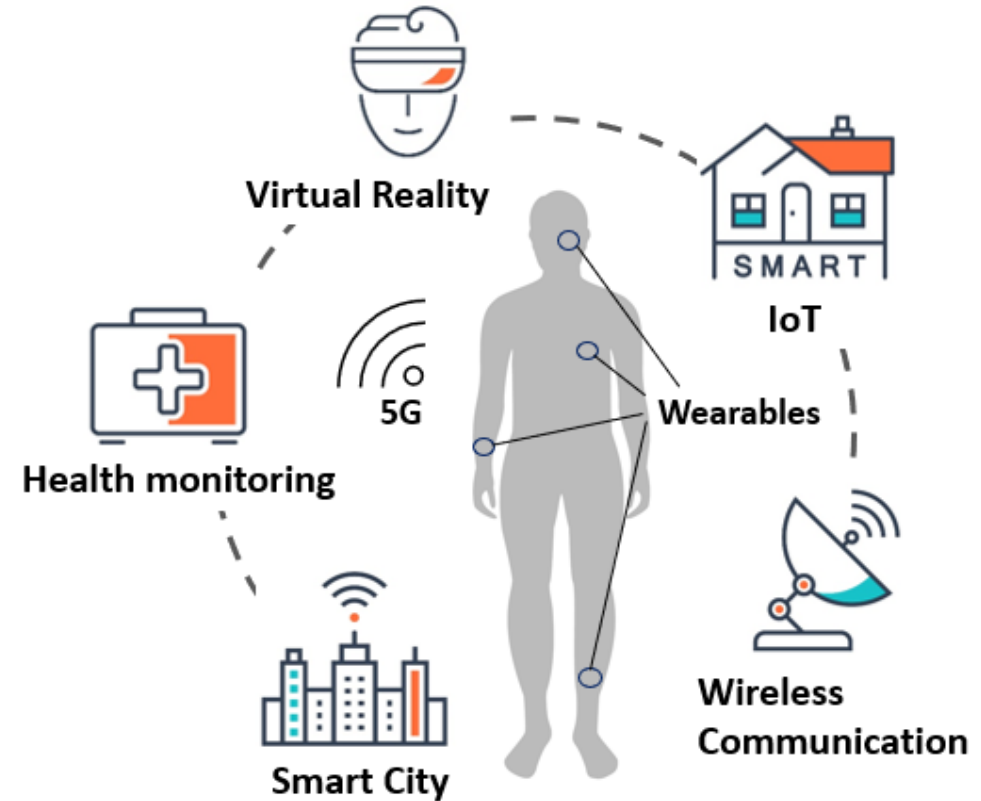
Additively Manufactured Flexible On-Package Phased Antenna Arrays with Integrated Microfluidic Cooling Channels for 5G/mmWave System-on-Package Designs

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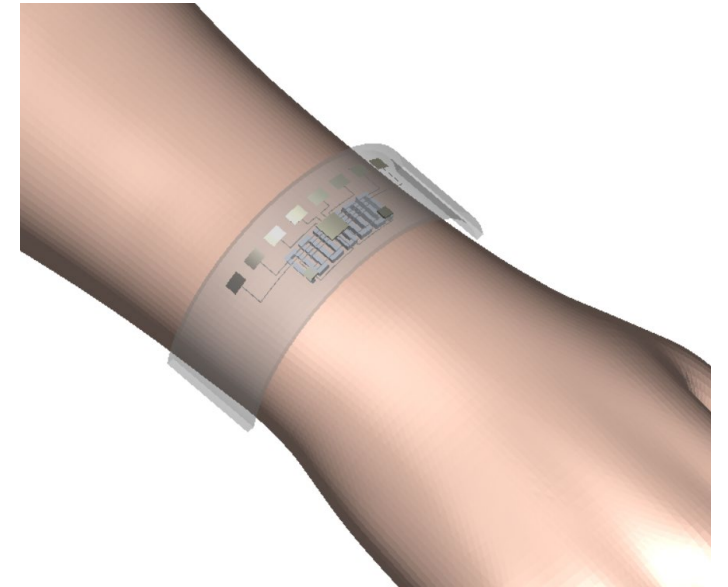
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- Motivation
- Challenges and proposed solution
- Design of a 2.5D UWB antenna array
- Integrated microfluidic channel
- Fabrication process
- Measurement results
- Conclusions
- Q&A

- Increasing demand for future System-on-Package designs
 - real-time response
 - deployable packaging
 - highly-integrated modules
- **Flexible phased arrays**
 - Support various platforms
 - adaptive beam steerability
 - deployable structures



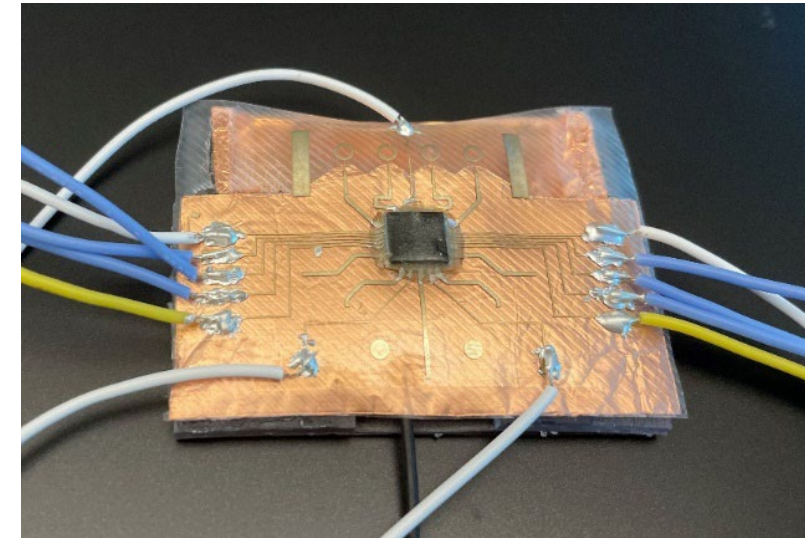
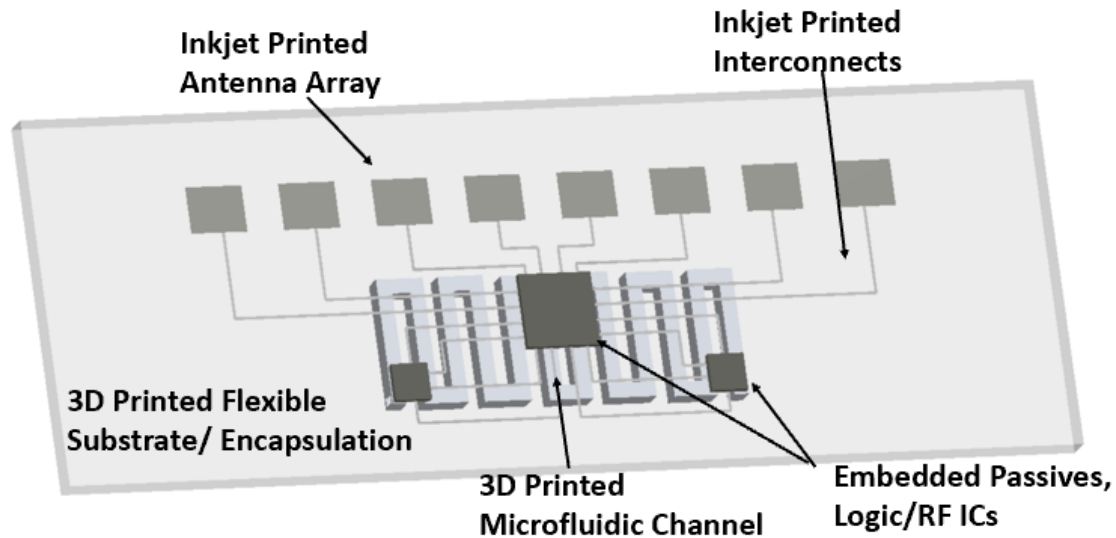
- **Need for Flexible hybrid electronics(FHE)**
 - Conformal in form factor
 - Resilient and adaptable performance to bending and on-body effects
 - Reliable both RF and mechanical perspectives
- **Advantages of additive manufacturing**
 - High customization
 - Low cost and less waste of materials
 - Wide range of flexible materials



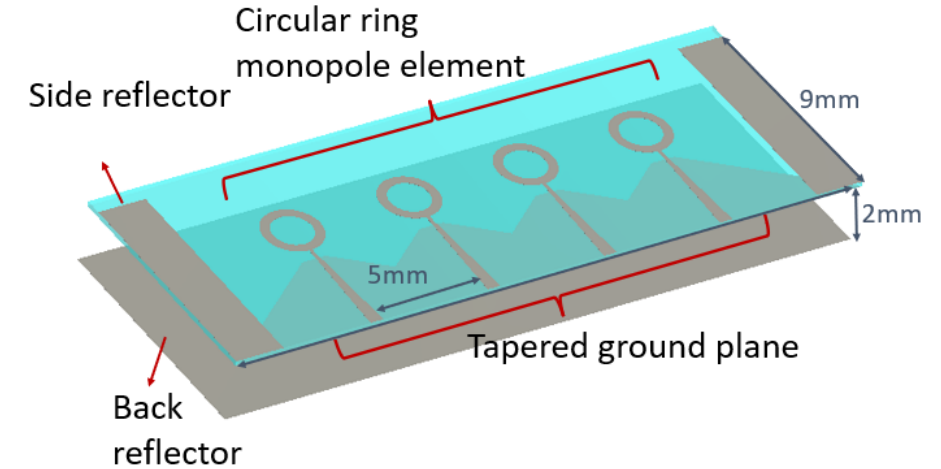
- 3D printed flexible materials sensitive to thermal treatment
 - Mechanical deformation
 - Deterioration of electrical performance
 - Difficult to attach RFICs
- Lack of material characterizations at mmWave frequencies
- Limited heat Dissipation due to poor thermal conductivity

Proposed Solution

- Inkjet printed 2.5D ultra-wideband antenna array
- 3D printed Polypropylene substrate and encapsulation
- 3D printed microfluidic channels
- Embedded RFICs with conductive epoxy



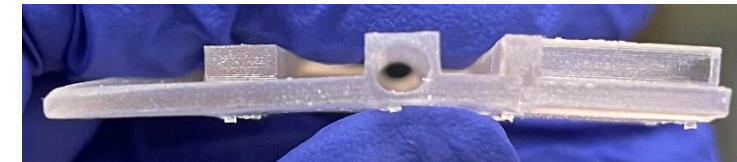
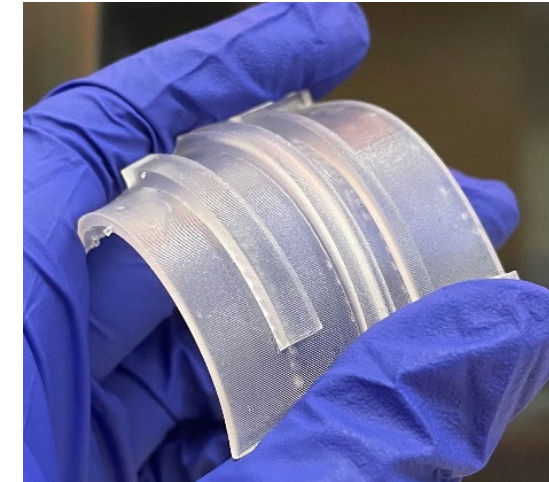
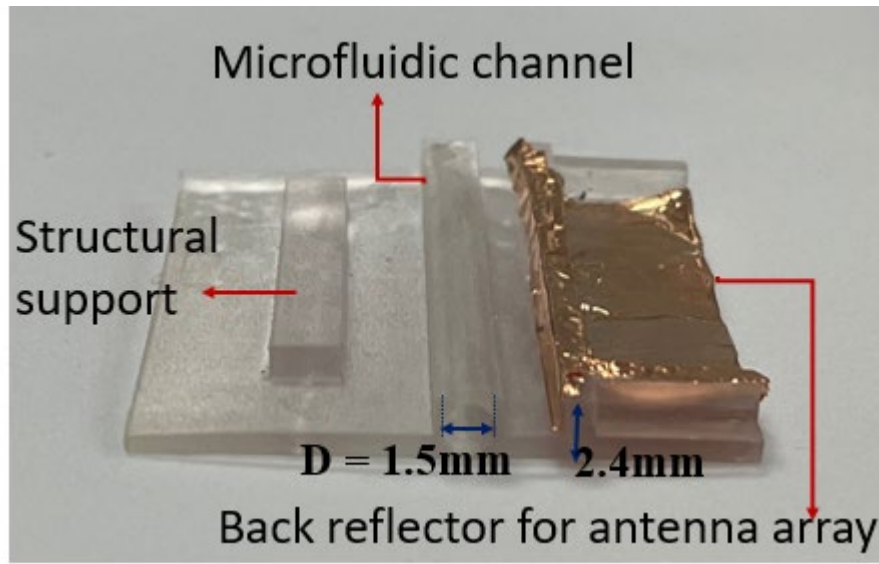
- Conventional UWB elements
 - Bulky and heavy
 - » Hard to integrate with packages
 - End-fire radiation pattern
 - » Not isolated from human body
- This design:
 - 2.5D structure using 3D printing
 - 24-40GHz bandwidth for 5G mmWave
 - Broadside radiation pattern



2.5D UWB antenna array

Integrated microfluidic channel

- SLA printed cylinder cooling pipe runs below the IC
 - Back reflector integrated with the module
 - No internal support required during printing
 - Structural support included



SLA printed microfluidic channels

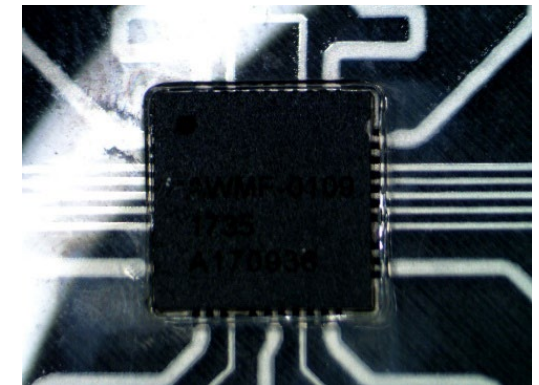
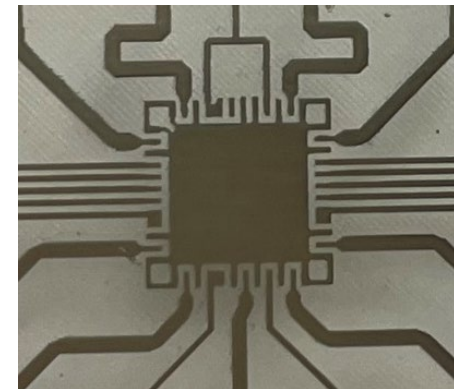
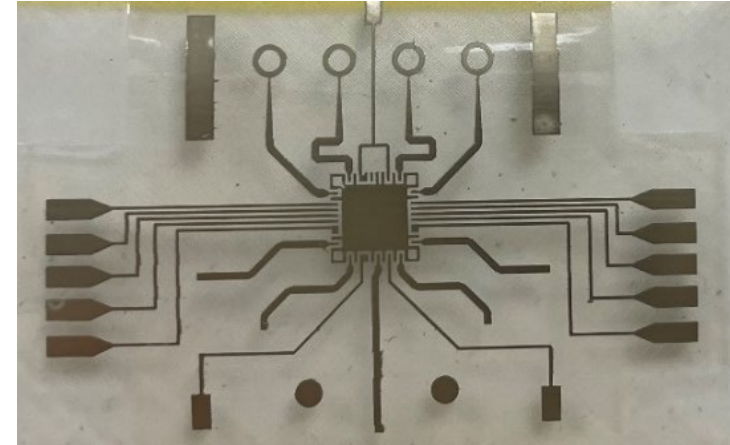
3D print 0.2mm thick
Polypropylene from
Ultimaker S3

Sand substrate surface and
apply 3 min UVO treatment

Inkjet print 2 layers of SU8
as buffer layers

Inkjet print antenna array
and IC footprint

Prepare IC stencil on PET



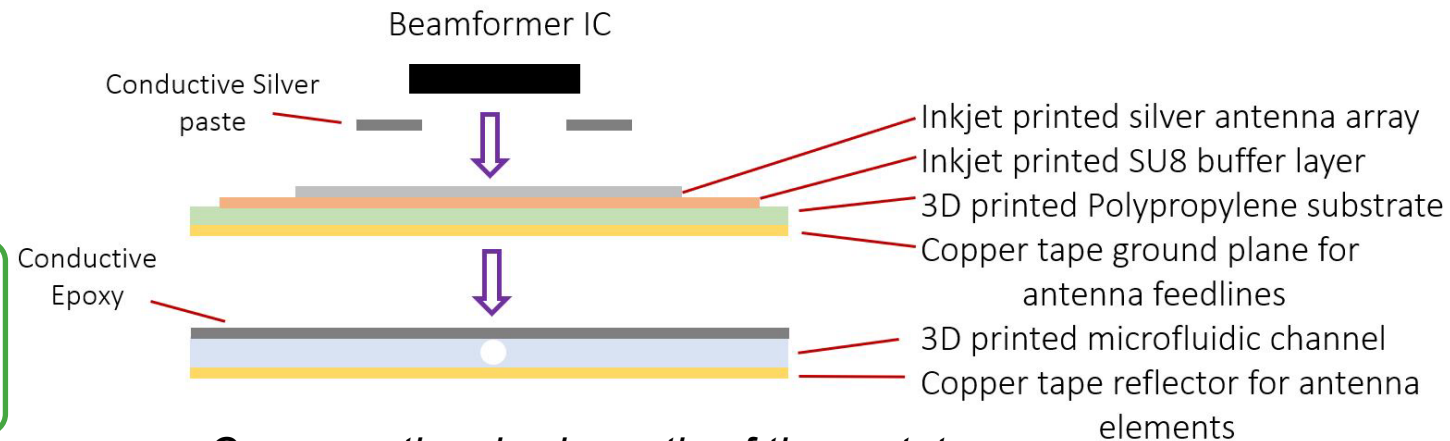
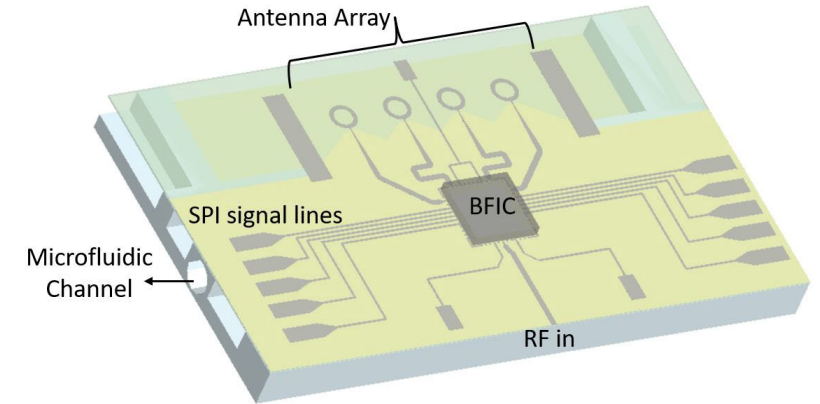
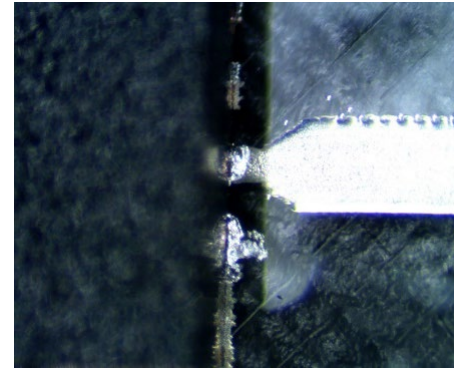
Inkjet printed pattern and PET stencil

Apply conductive epoxy
on each pin

Cure under uniform
pressure and heat

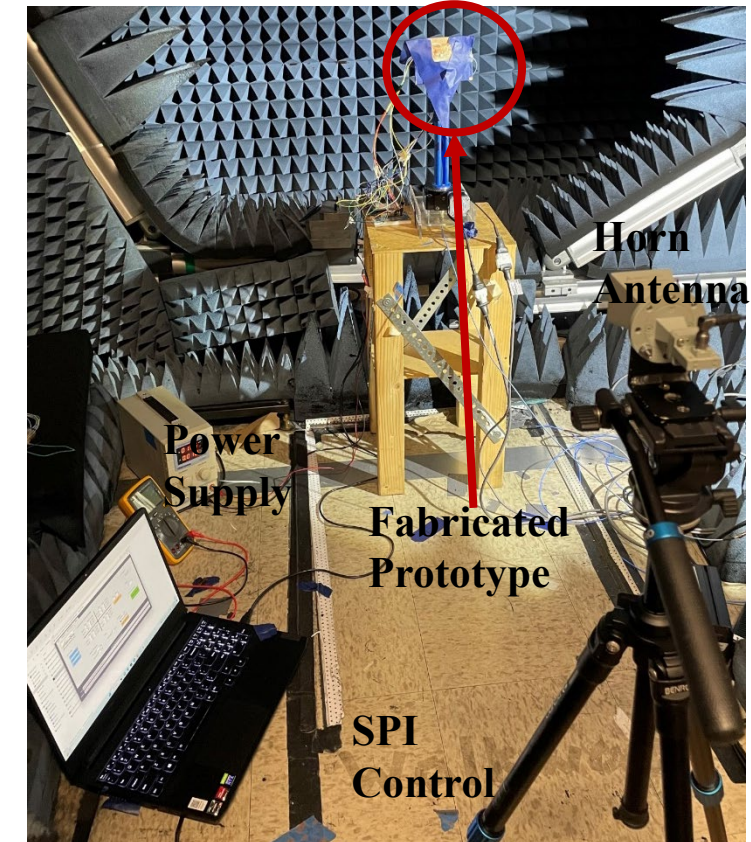
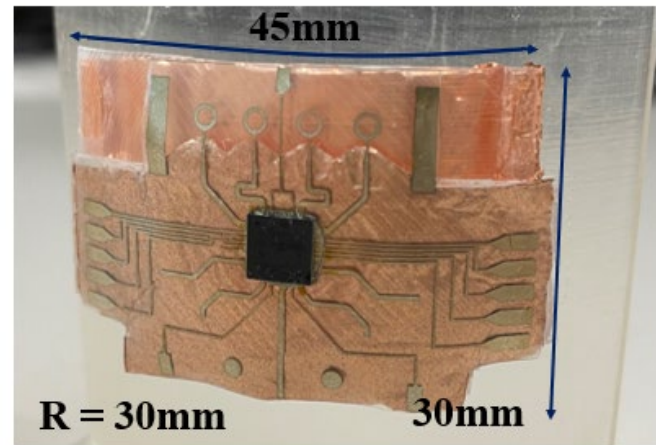
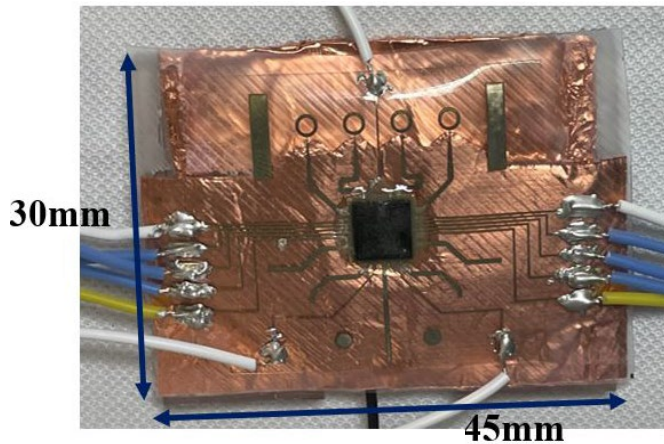
Apply ACA material
surrounding the IC

Attach to the microfluidic
module

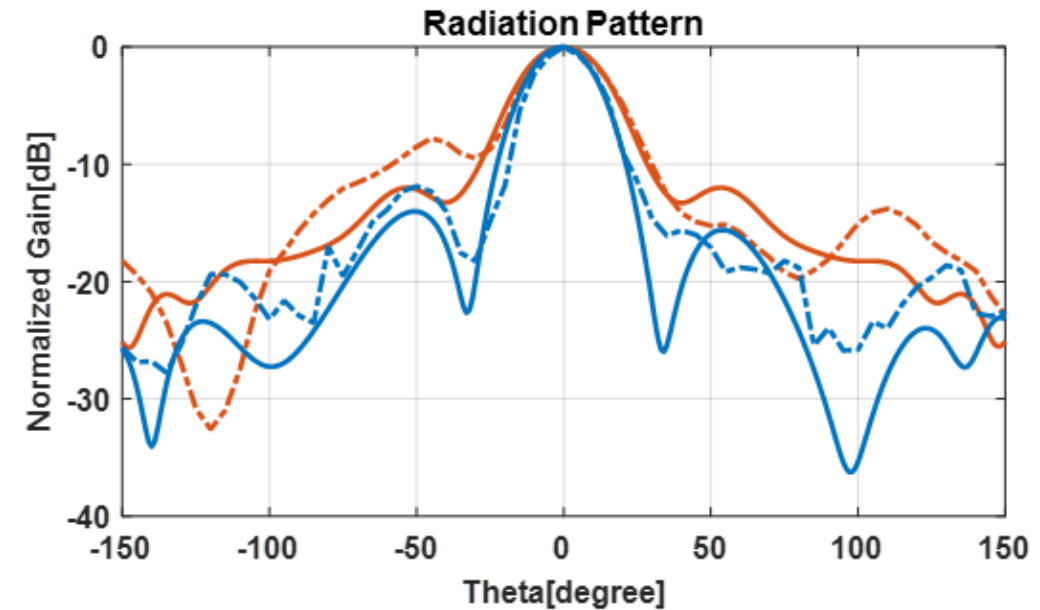
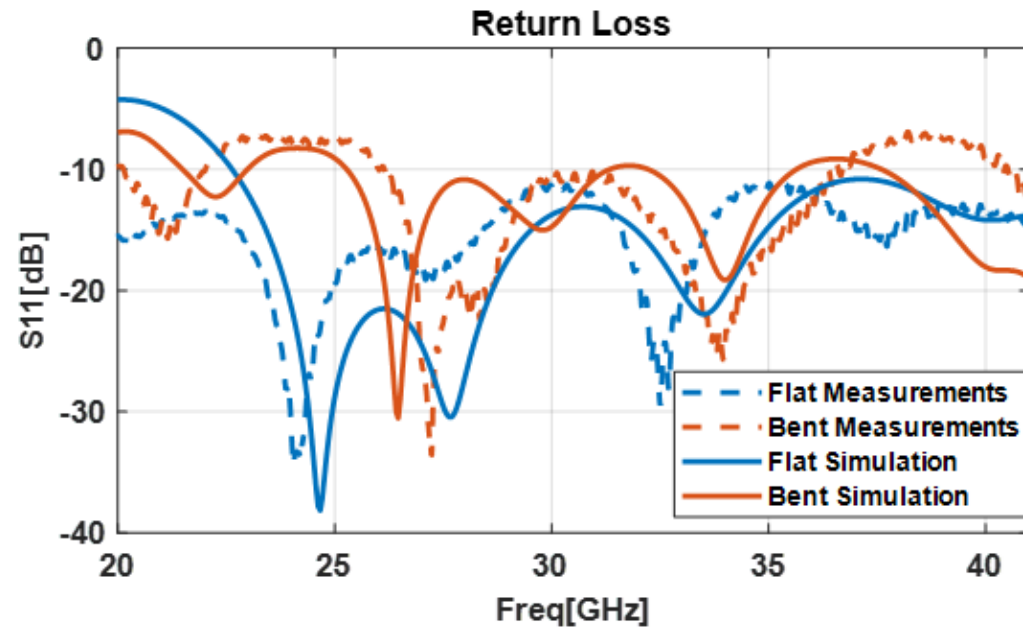


Cross-sectional schematic of the prototype

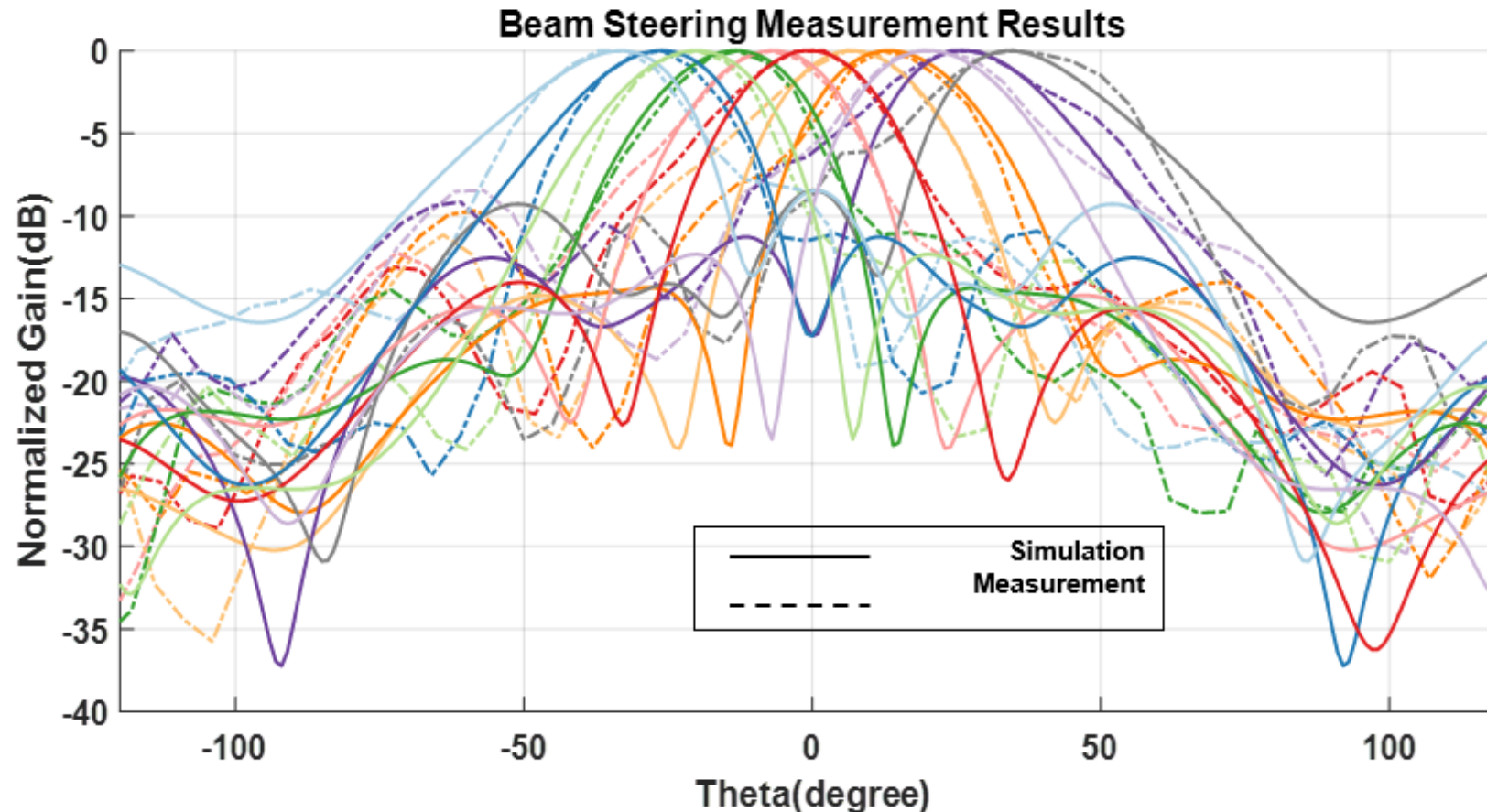
- Measurement setup in an anechoic chamber
- SPI control using Matlab program
- DC power supply
- Flat and bent conditions



- Flat vs. bent conditions:
 - the change in impedance matching and element spacing
 - » shift the operational frequencies
 - » slightly increase the beamwidth and side lobe level

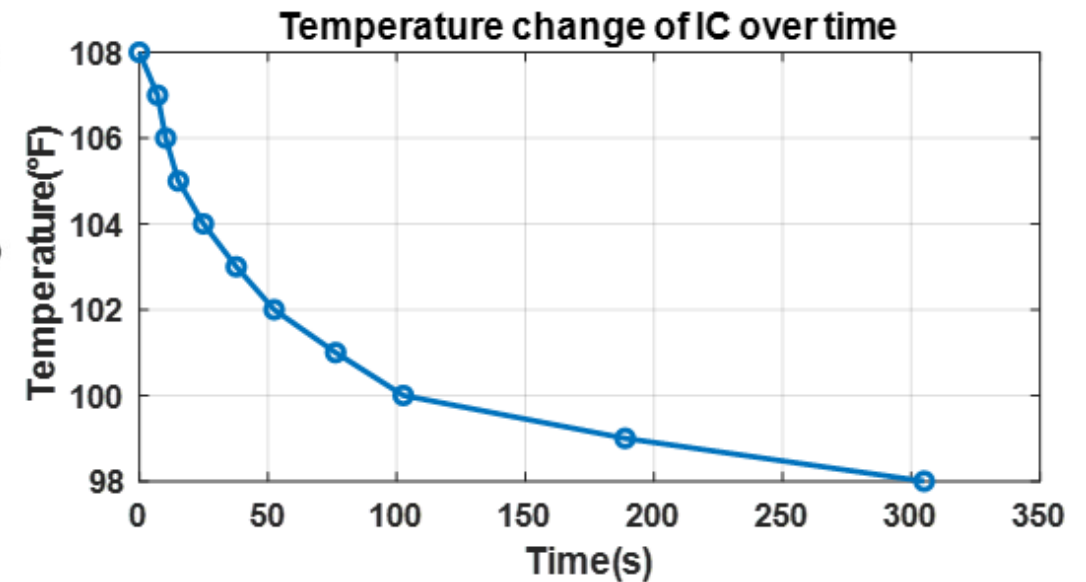
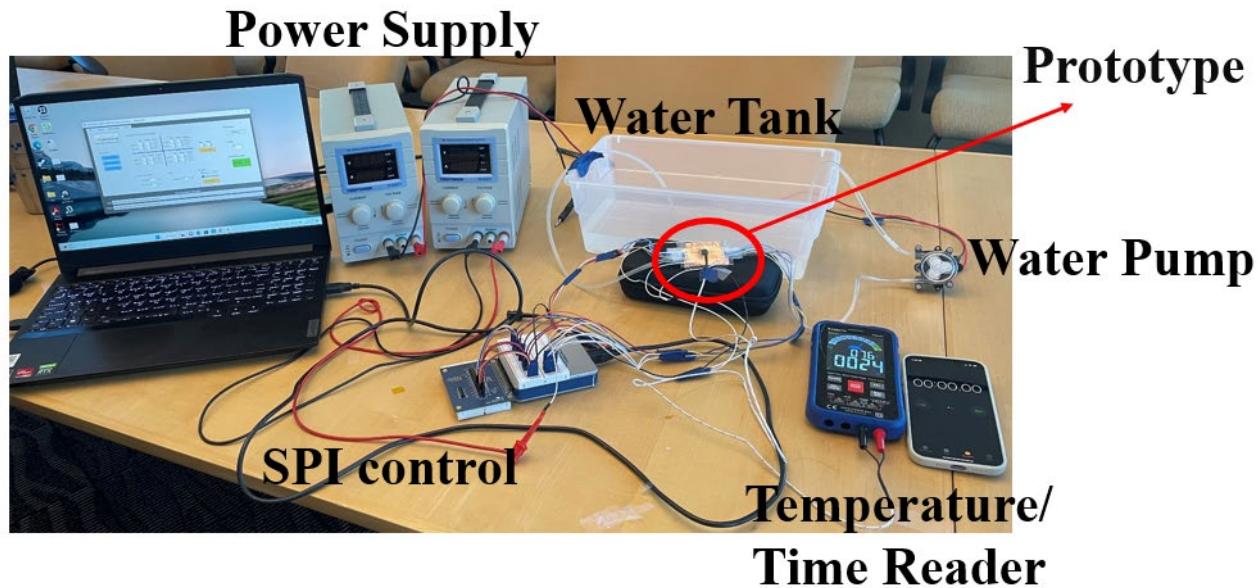


- Beam steering from -37° to $+37^\circ$
 - -10.09dBi maximum realized gain and -8.45dB sidelobe level



Measurements

- Water pumped through the channel at 1.45 mL/s
- Temperature measured at the surface of the IC
- 108°F to 98°F in 5min
- Estimated heat dissipation 1.052W



Conclusions

- The first fully additively manufactured flexible on-package phased array with an integrated microfluidic channel.
- The attached beamformer IC is sustainable for practical bending radii in flexible wearable applications.
- Sufficient mitigation of IC temperatures is provided by the microfluidic channel.
- Low-temperature IC alignment/assembly process combined with AM can be applied to flexible MCM and SoP designs.

Thanks!

Q&A