WE1G-5

Industry Keynote Paper

A Next-Generation Hybrid Analog Beamsteering and MIMO Digital Radar for Highly Automated Driving

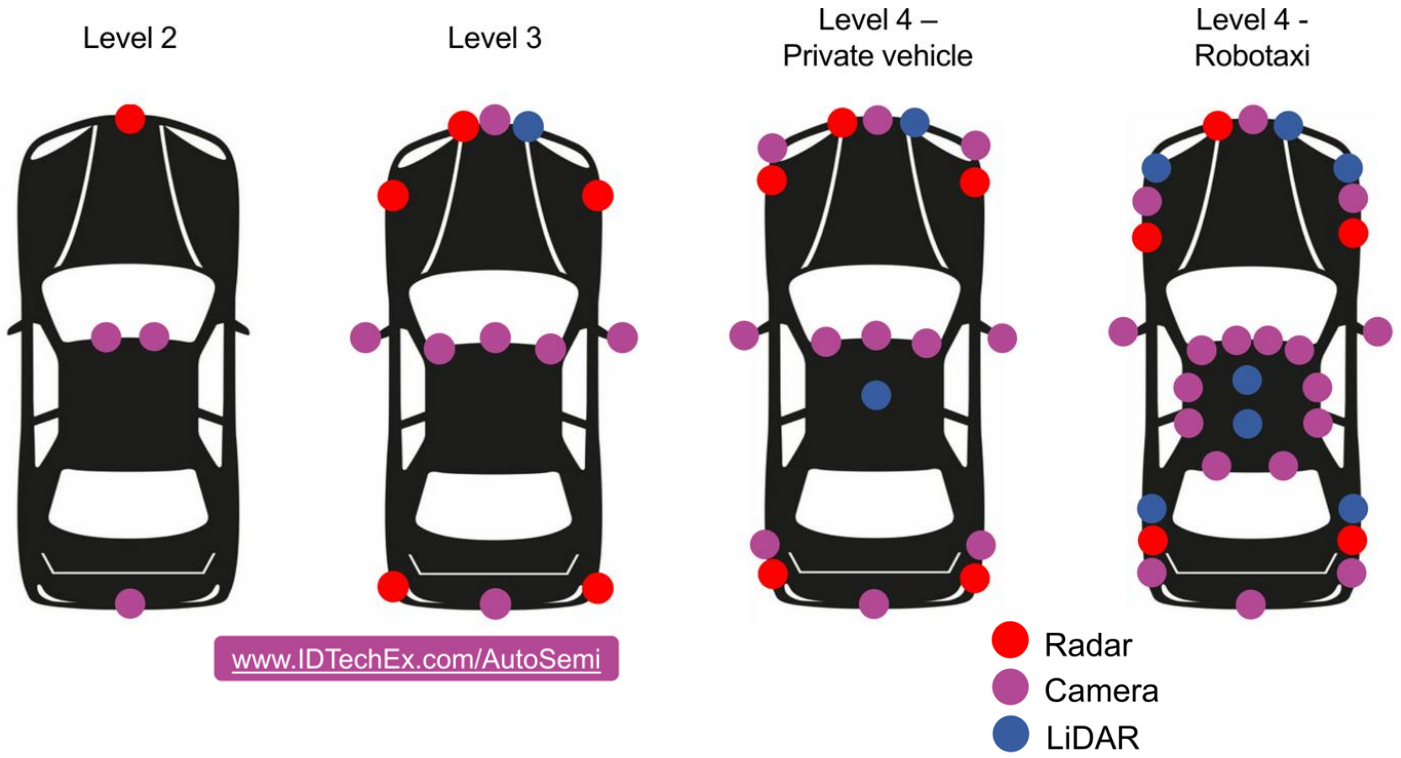
Kevin Gu

Metawave Corporation

Outline

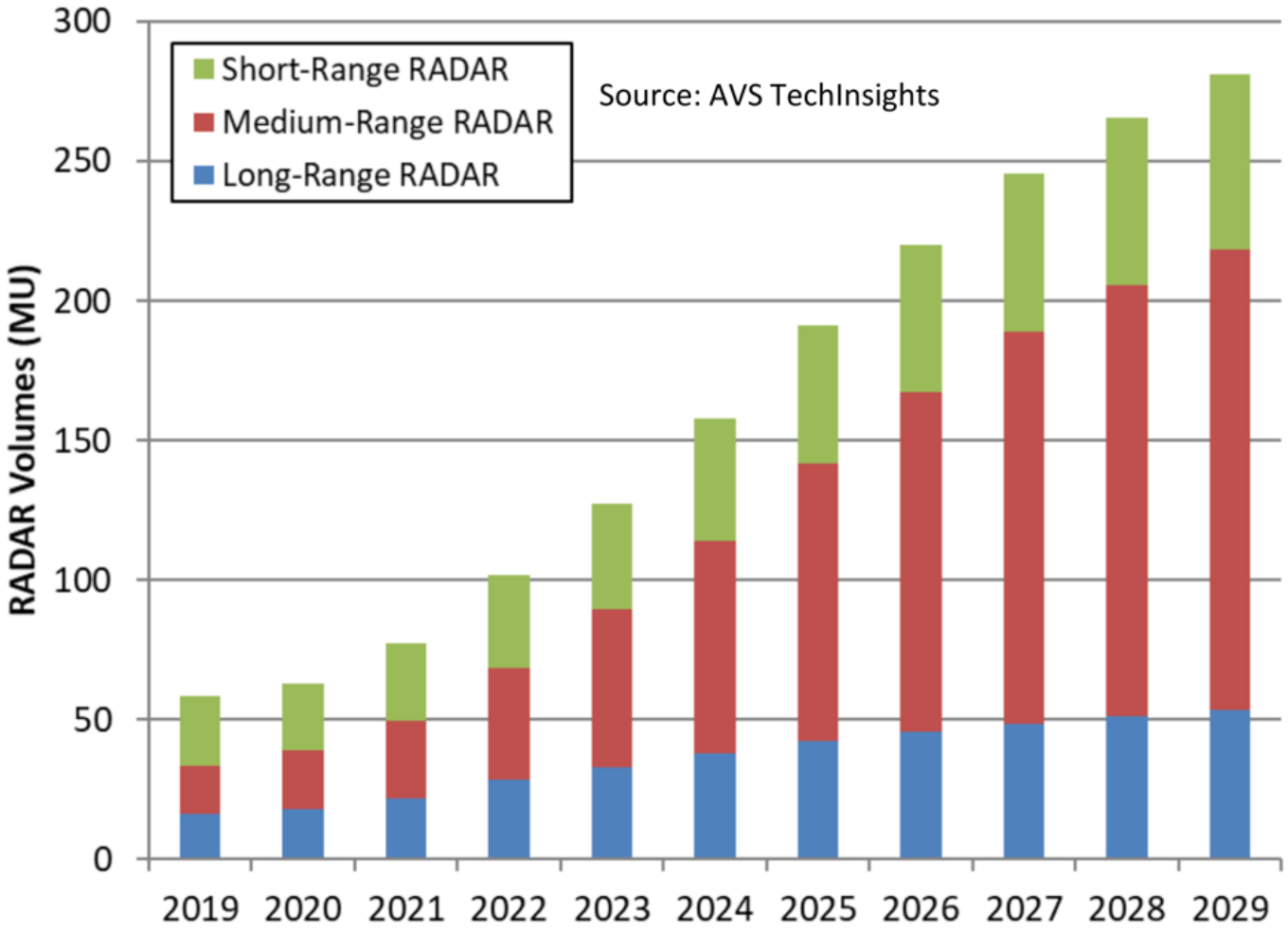
- Motivation and introduction of a long-range hybrid (beamsteering + MIMO) imaging radar
- Metawave Carson radar design and implementation
  - Beamformer TX/RX IC
  - Antenna-in-Package
  - System design, implementation, and RF performance
- Radar demo video
- Conclusions

Introduction

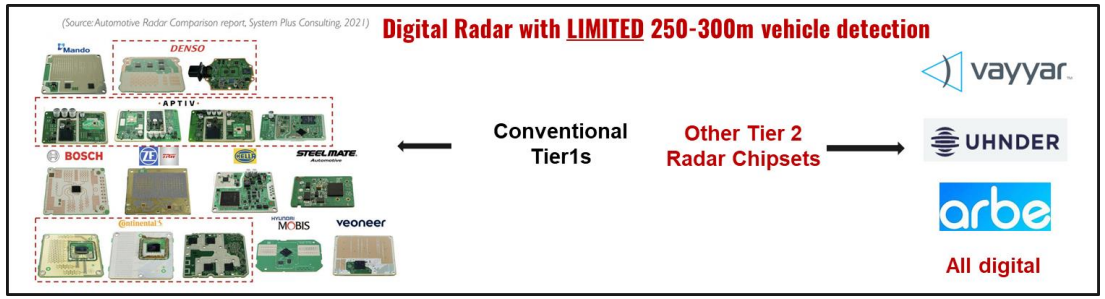


- Sensor suite evolution for L2 – L5 driving: more features and increased demand for robustness requires more sensors.
- Radar is a core sensor to cope with challenging weather conditions.

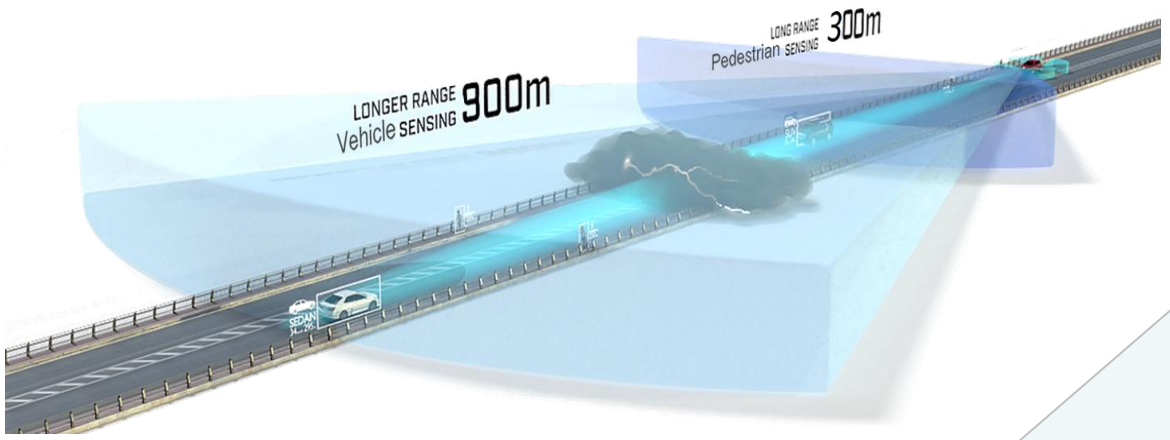
Introduction

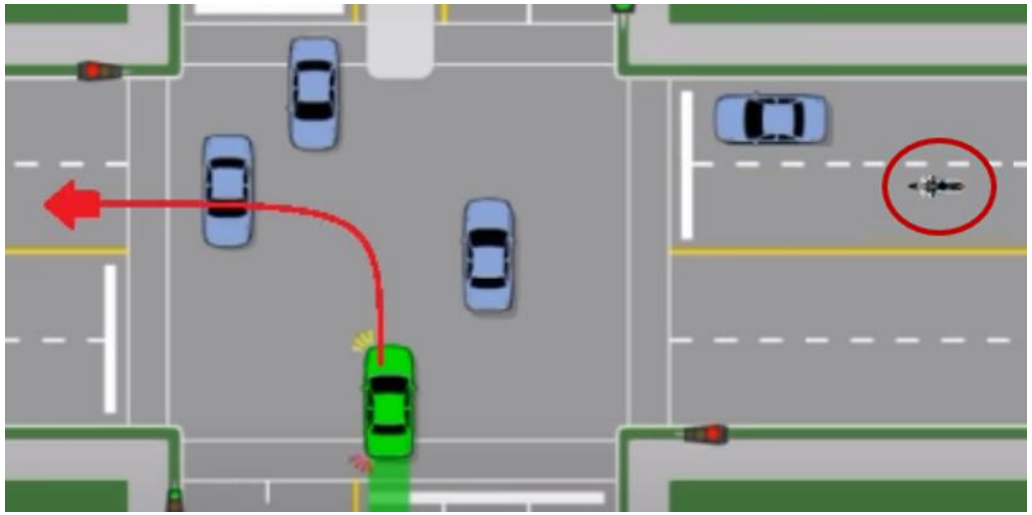


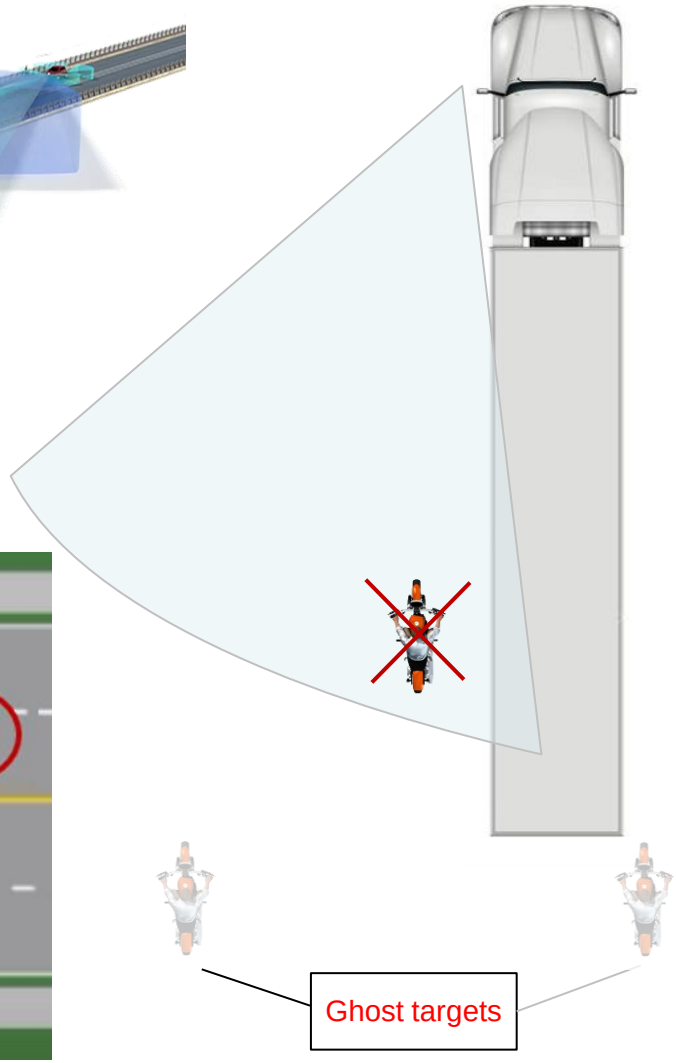
- Strong growth forecast for automotive radar
- Accelerated adoption of 4D imaging radar: distance + direction + velocity + elevation



Introduction





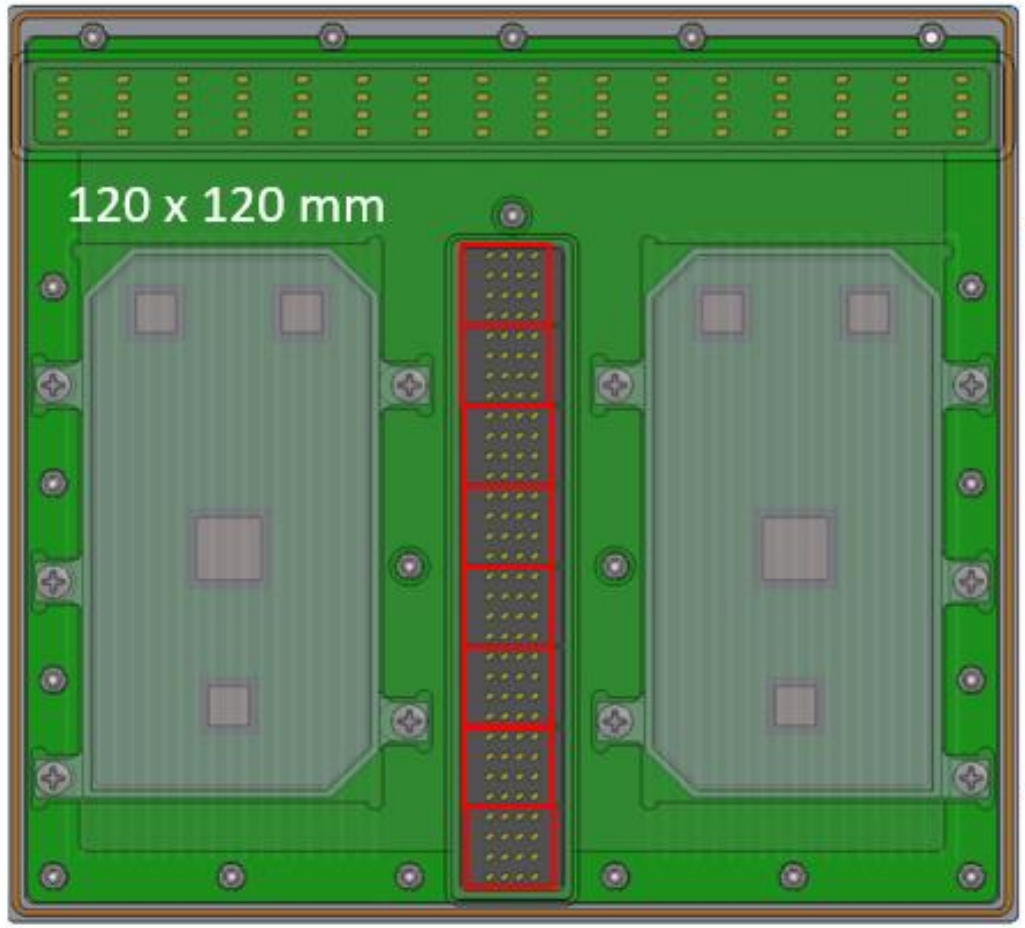


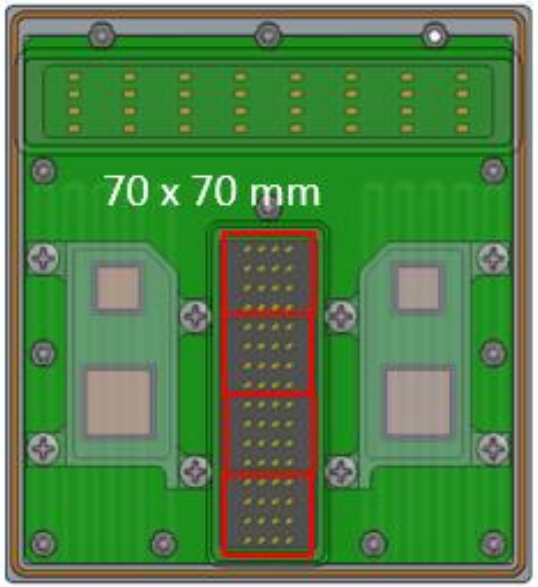
Technical Challenges for MIMO-based radars:

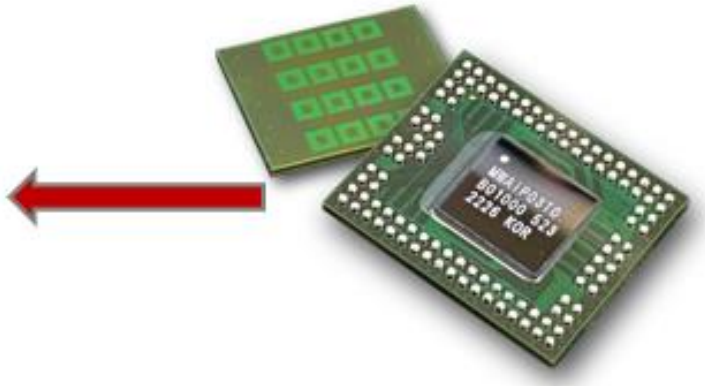
- Long range detection (e.g., 900m for car, 300m for pedestrian)
- Corner radar detecting motorcycle at 250m
- Truck rear-view long-range detection, e.g., mitigate multipath effects & eliminate ghost targets

Carson Imaging Radar Hardware

- 16-element TX/RX Beamformer IC
- 4x4 Antenna-in-Package
- Scalable architecture (center/corner radars)

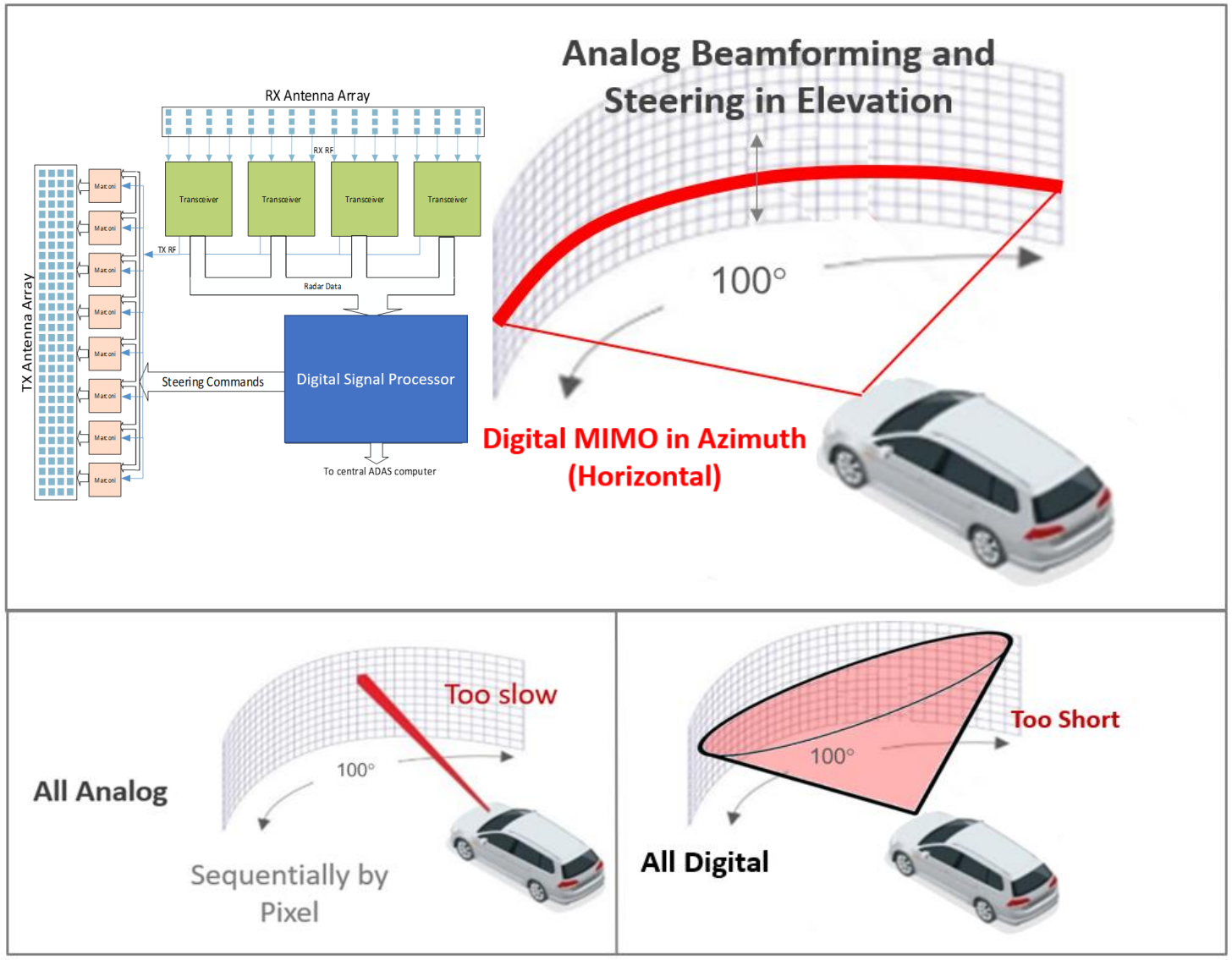






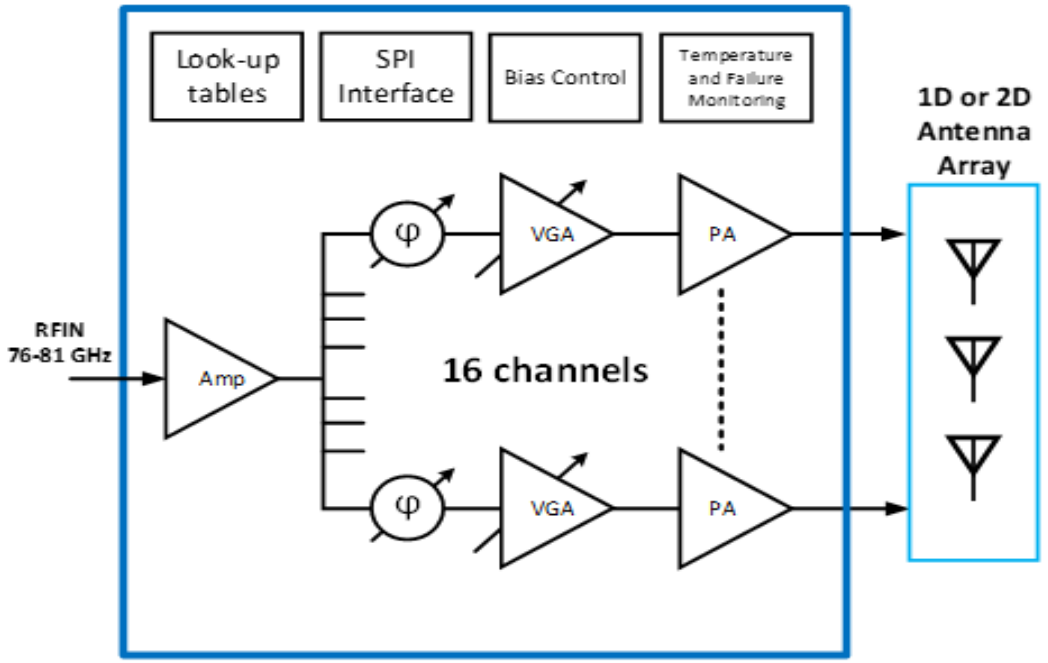
- ✓ Lower Cost
- ✓ Scalability
- ✓ Flexibility

Hybrid Radar Architecture

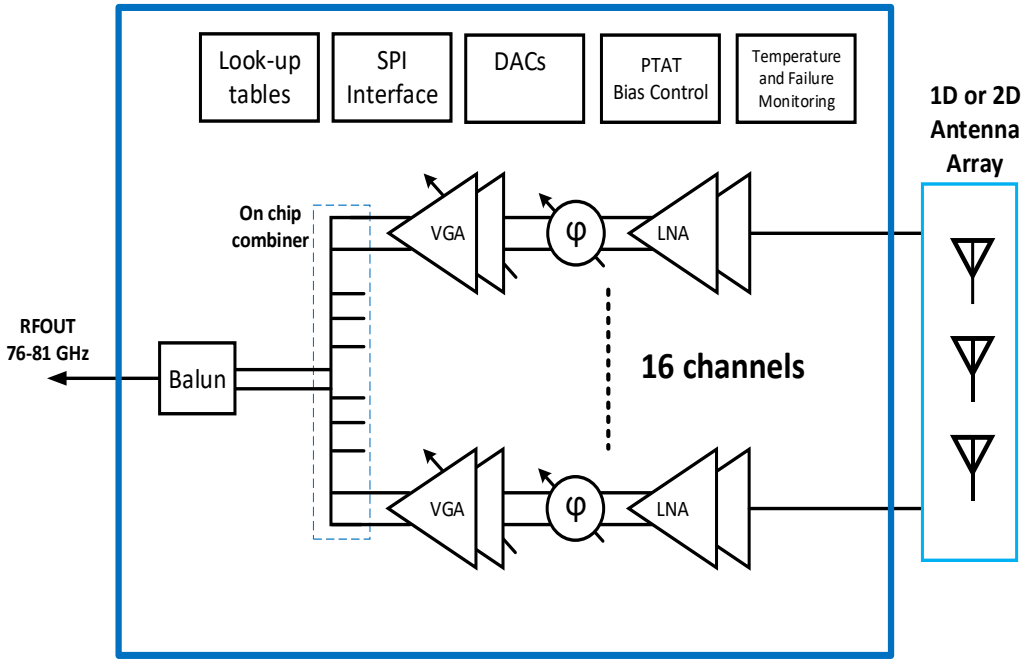


- Analog elevation beam steering
  - 32 elements in elevation for Tx beam steering in elevation
- Digital MIMO for target azimuth estimation
  - 16 RX antennas
  - 64 elements virtual array
- DDMA (Doppler Division Multiple Access) waveform for MIMO

Marconi TX/RF Beamformer IC



16 Channel Transmit Beamformer

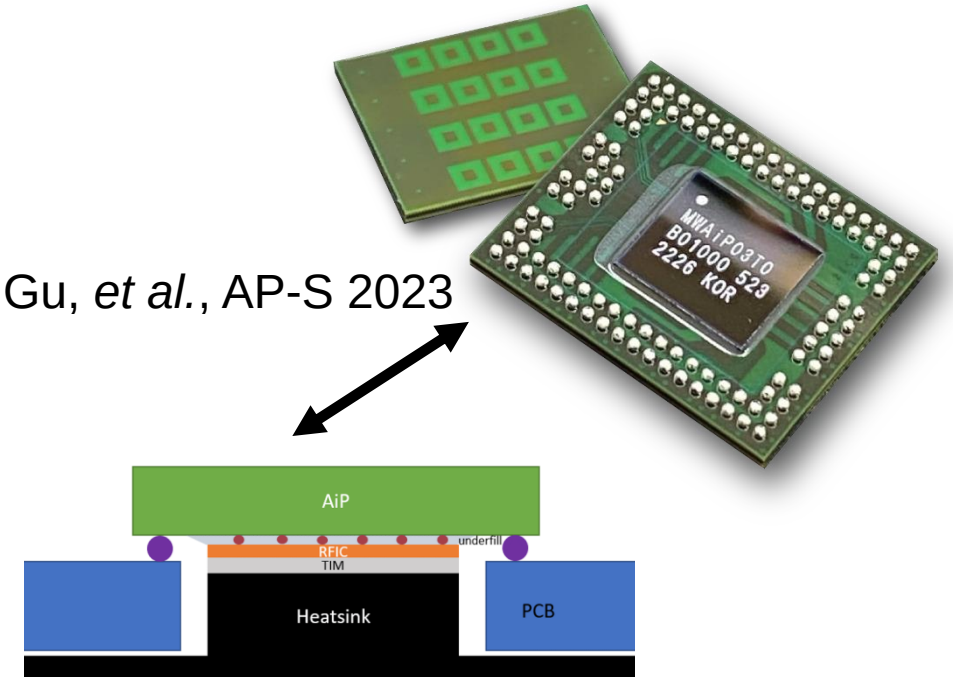


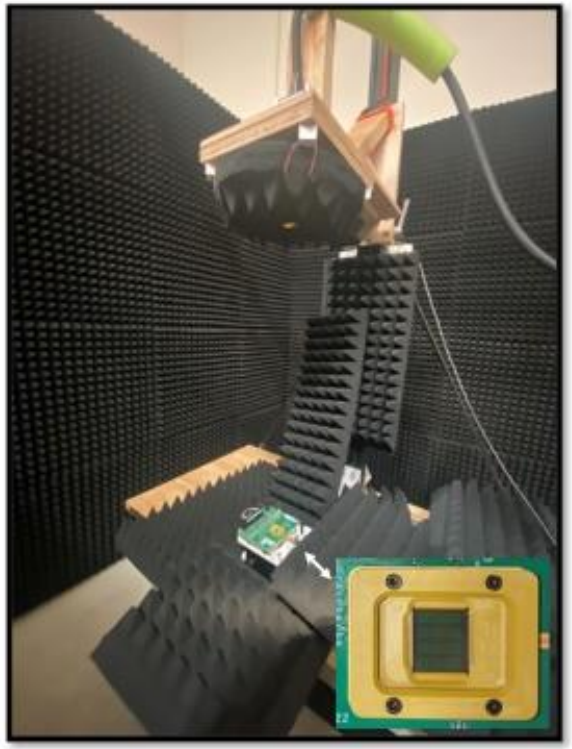
16 Channel Receive Beamformer

- Die size: 5.4mm x 4.8mm (with 0.2mm-pitch C4s)
- Each frontend has PA/LNA, VGA, phase shifter, power splitter, SPI, DAC, temperature sensor, ESD protection, etc.

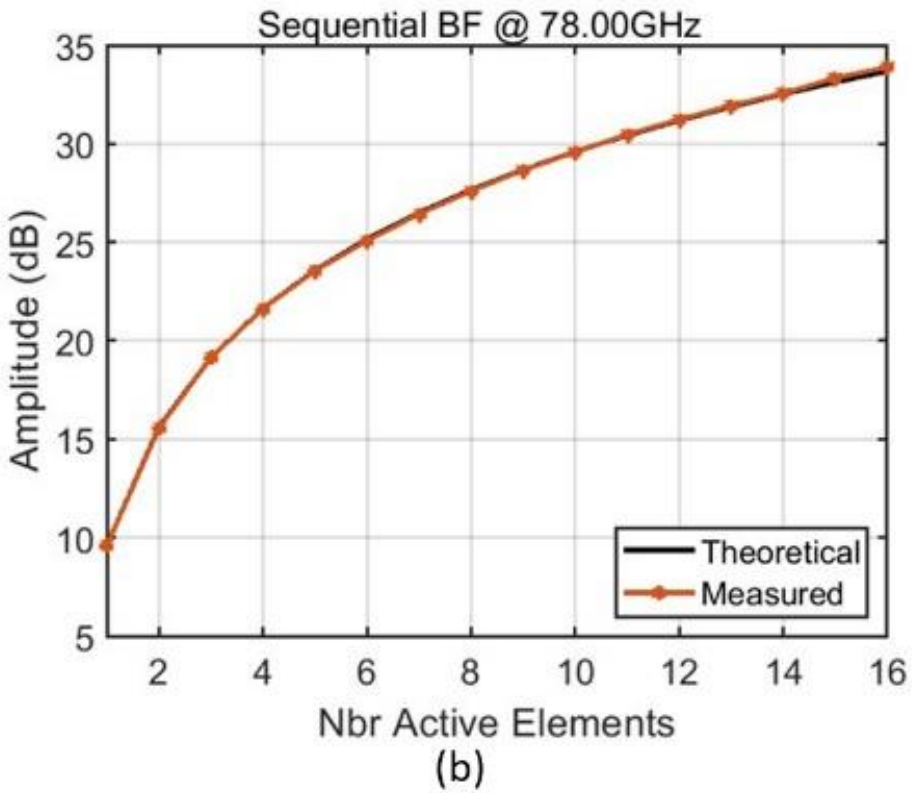
Antenna-in-Package Design and Test

Gu, *et al.*, AP-S 2023





(a)

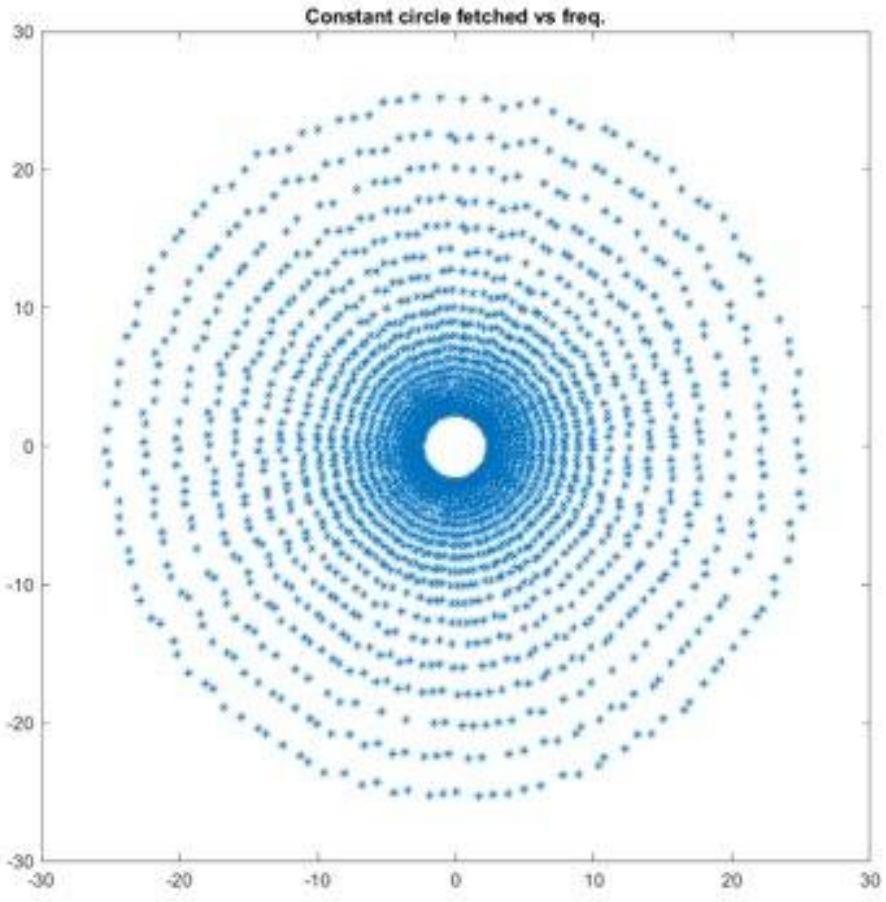


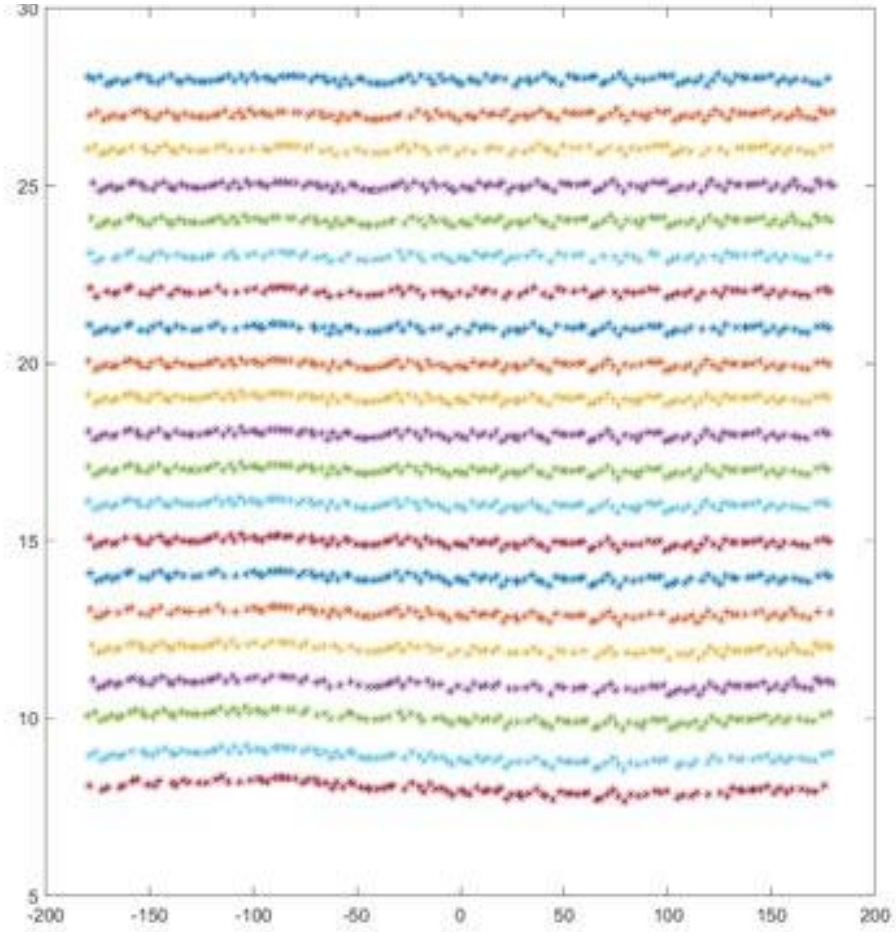
(b)

- Mass-producible flip-chip AiP (12.4mm x 10.2mm x 1.1mm)
- TX module OTA calibration: excellent power combining demonstrated

Amplitude and Phase Control Results

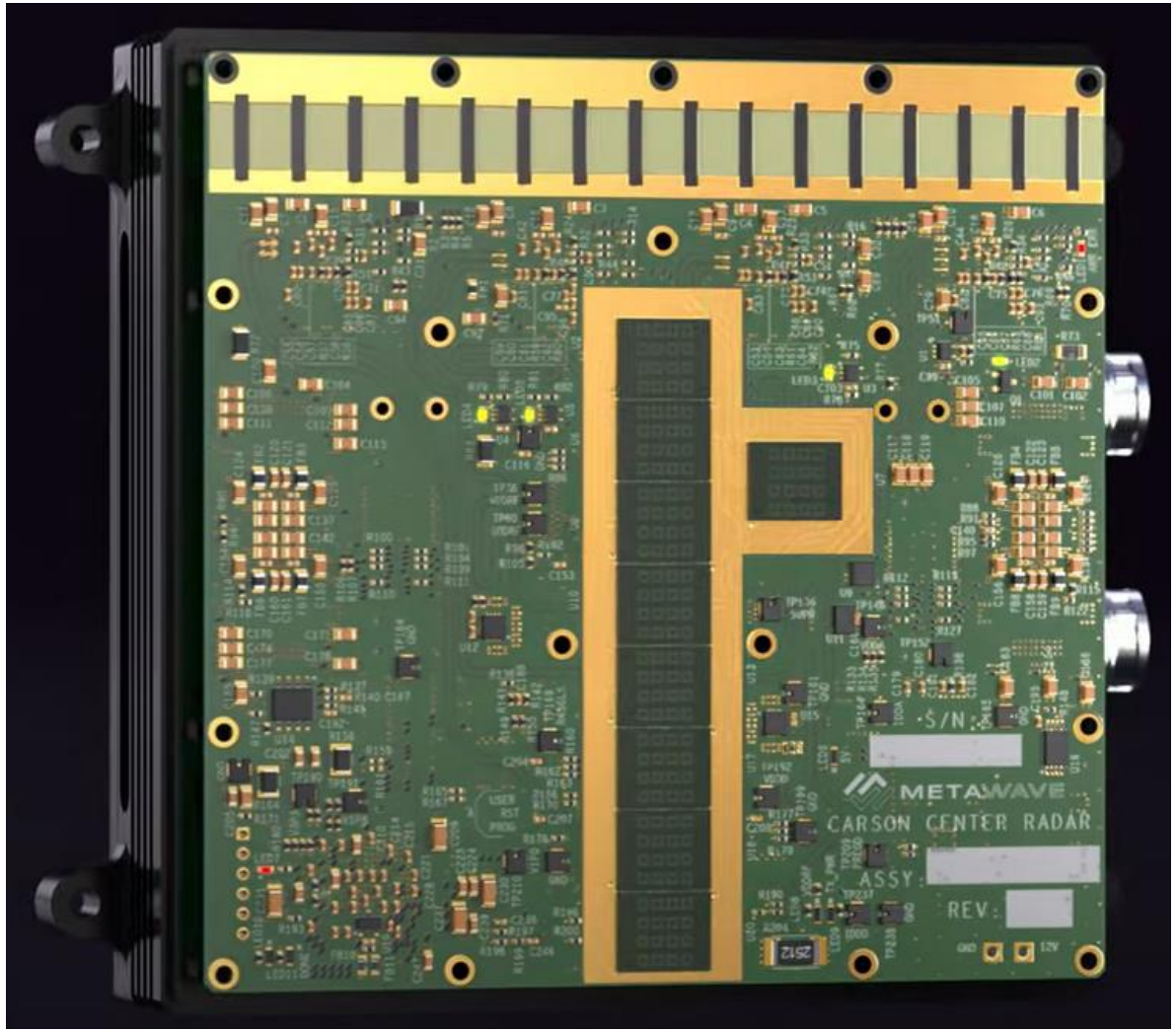
One representative channel at 77GHz





- 2.8 phase step, <0.5dB Amp step, <0.5dB variation over phase shifting

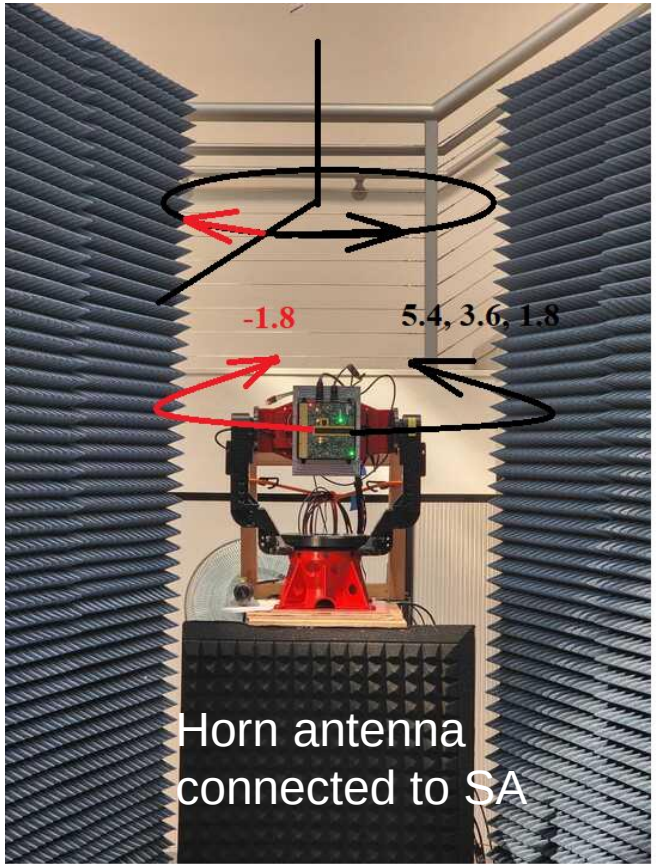
Carson Imaging Radar Implementation

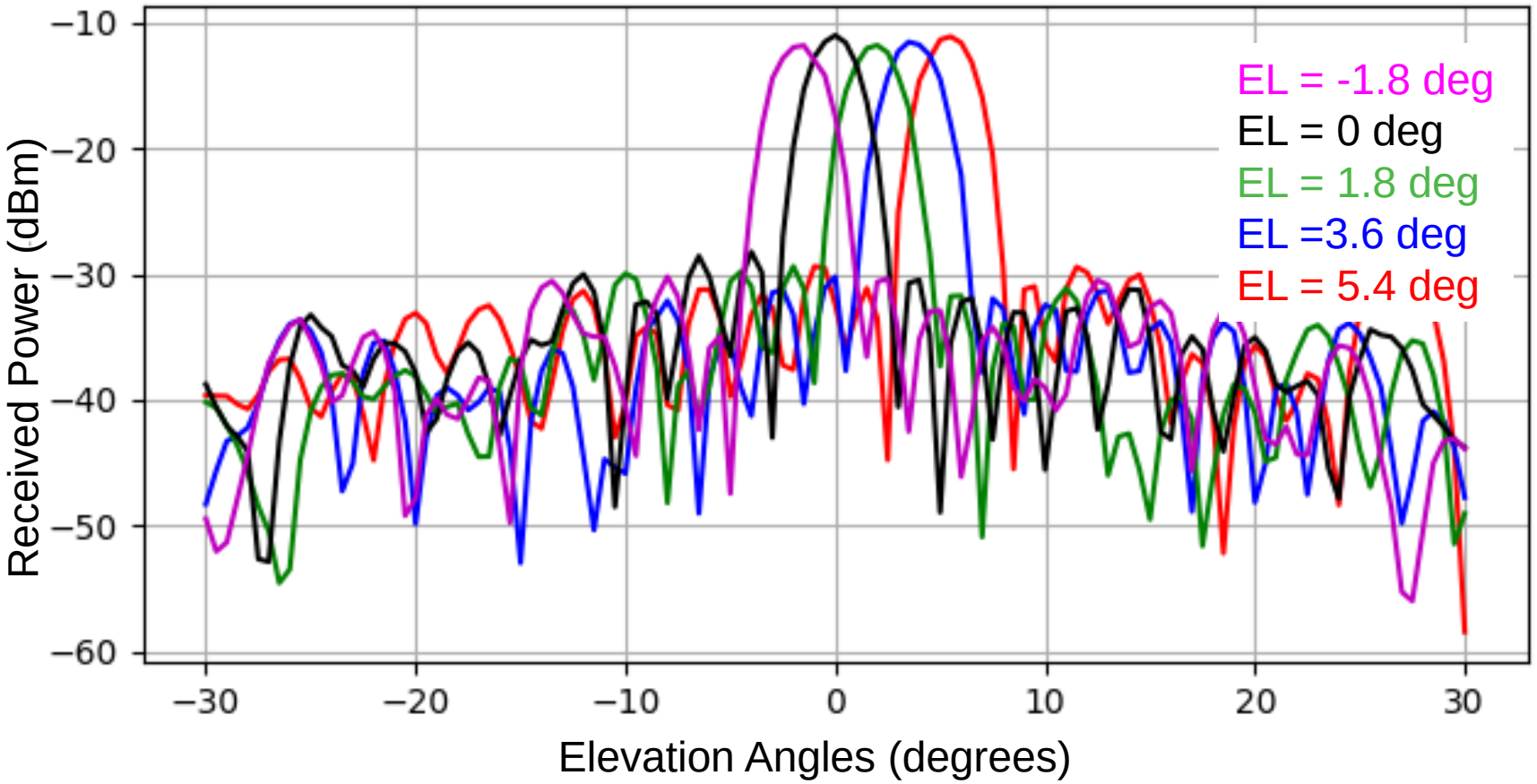


12cm x 12cm
with front cover &
NXP processor board

- TX Marconi AiPs (x8) + 1 Guard AiP (for testing purpose only)
- RX Antenna Array (2λ spacing)
- 4x Cascade RF TI Transceivers on the back
- NXP Processor inside Radar Unit

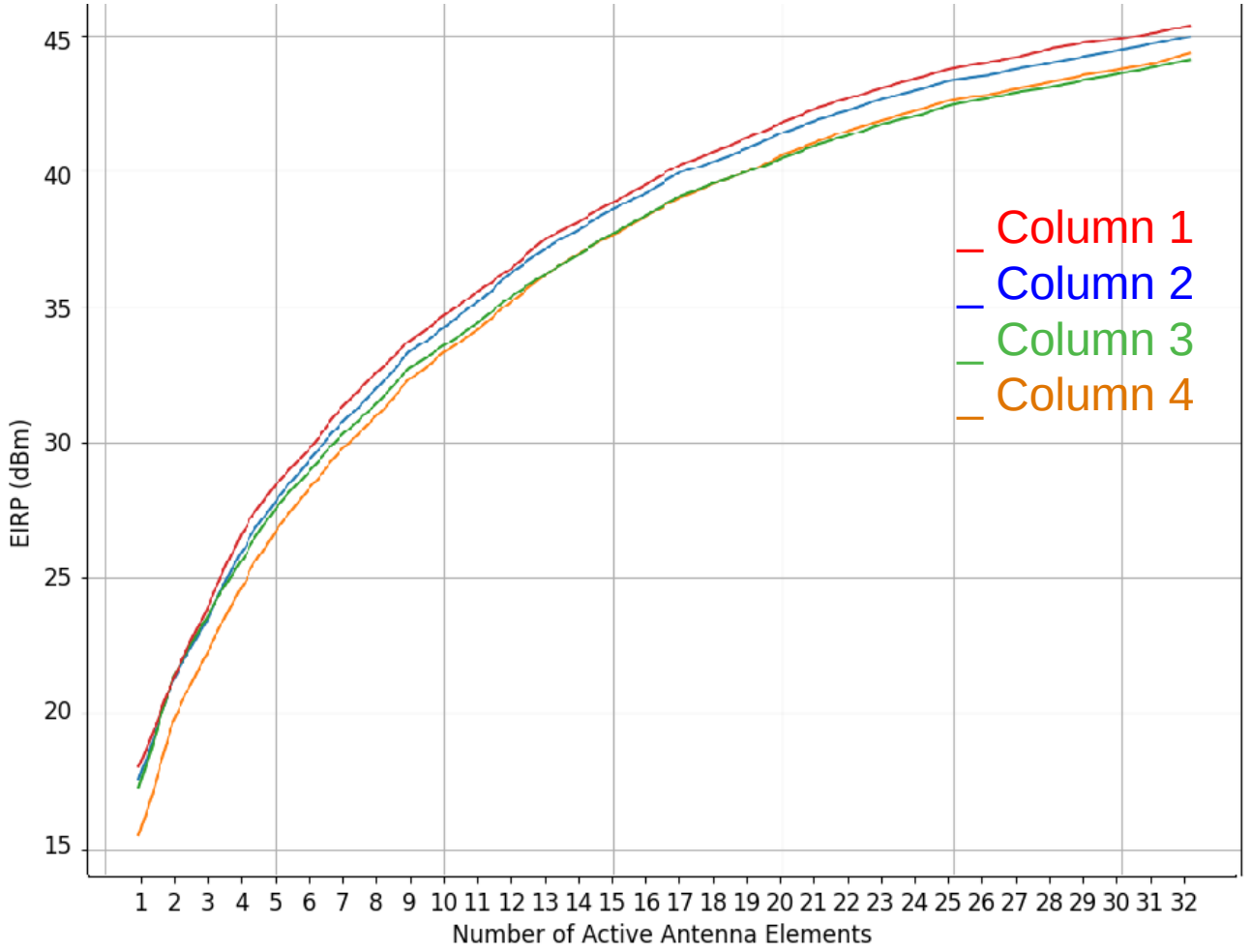
TX Elevation Beam Steering Calibration





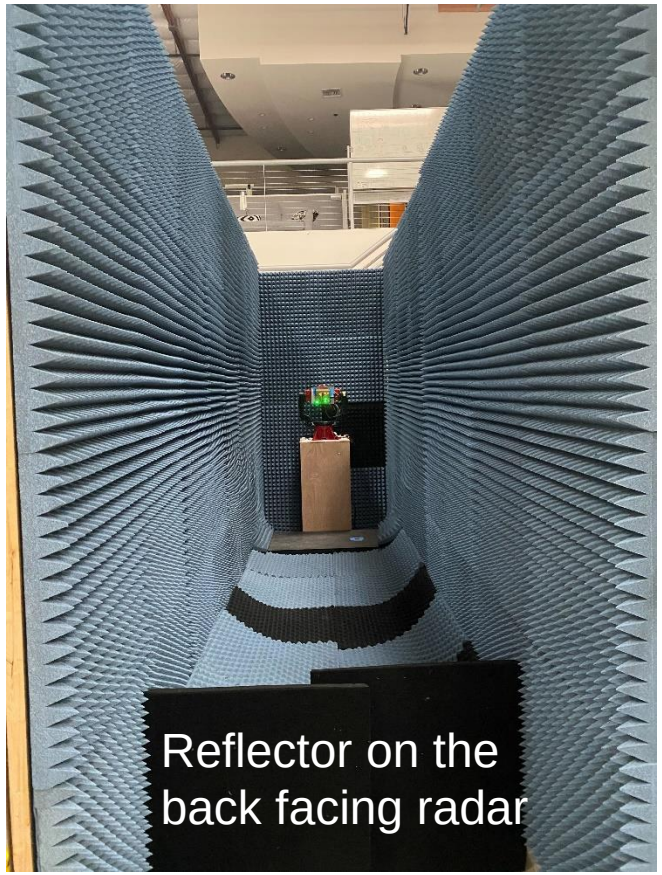
- Multiple EL beams generated by an innovative calibration method
- Measured half-power beam width = 2.2 degrees

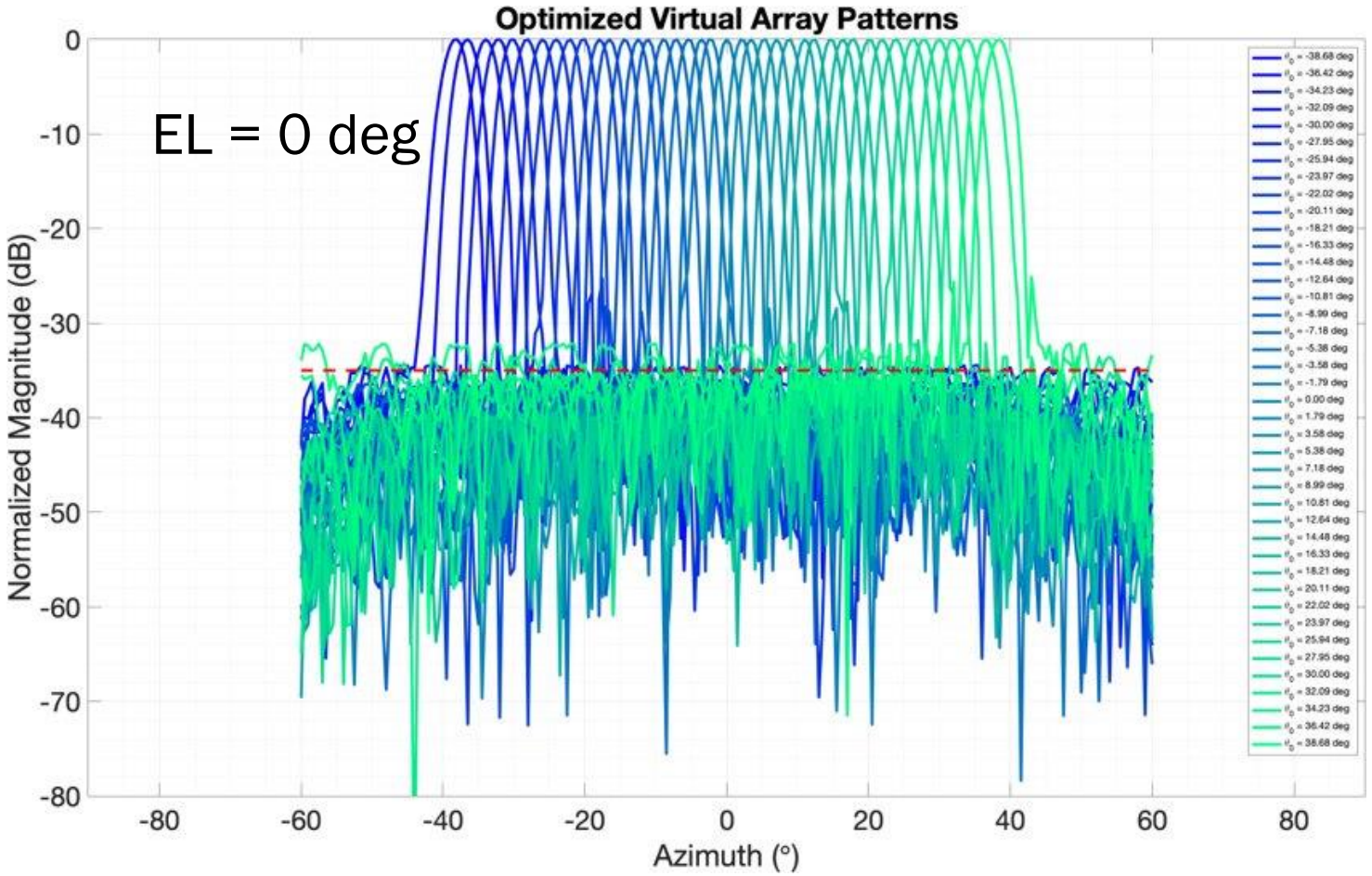
TX OTA Power Combining and EIRP Measurement



- CW mode at 78 GHz
- 27dB increase for four 32-element TX columns
- Measured EIRP (32-element per column): 43.5 dBm (average)
- Measured EIPR (128 elements): 53.5 dBm

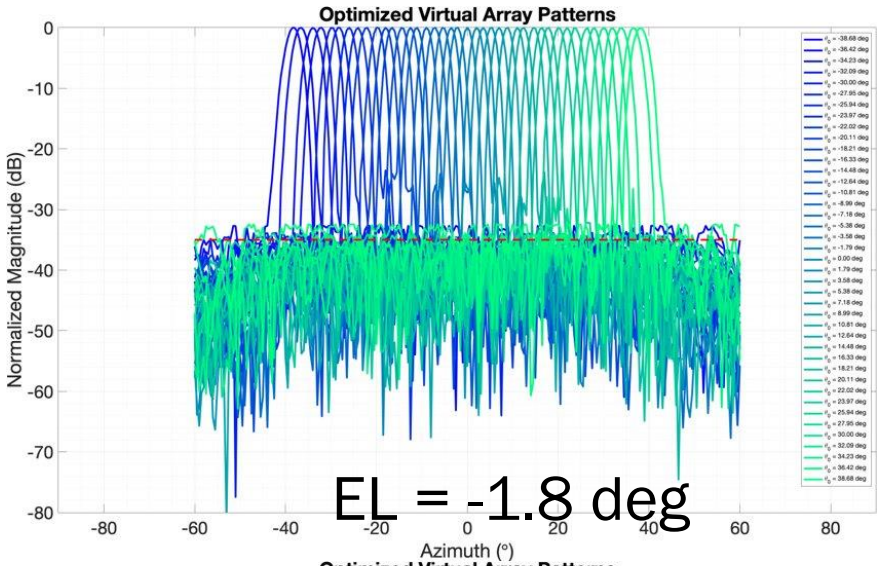
Azimuth MIMO Calibration with DDMA

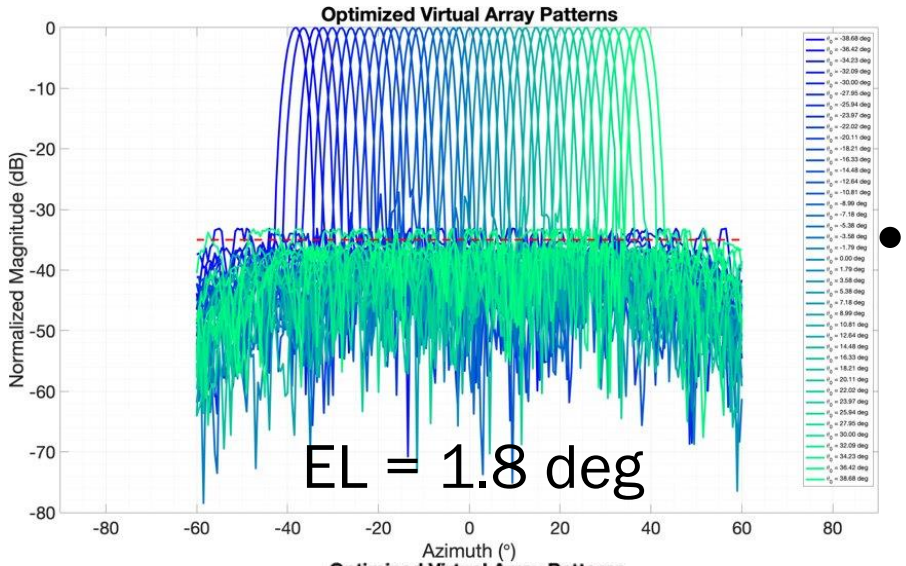


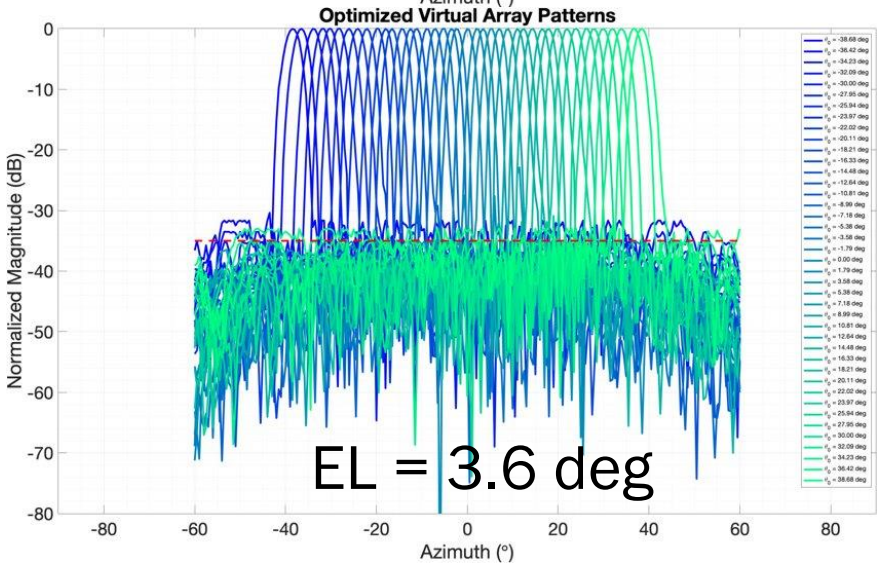


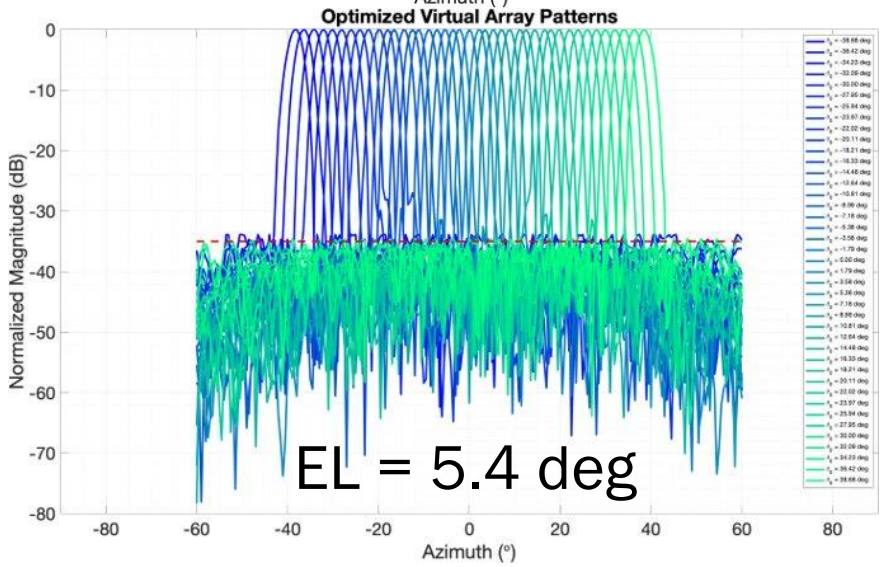
- Narrow beams with ultra low (> 35dB) side-lobe levels

Azimuth MIMO Calibration with DDMA









- Excellent virtual array beam patterns in other EL directions

Carson Radar Demo Video

Road test demo video will be played during the presentation

Conclusions

- Increasing demand for automotive imaging radar.
- Digital MIMO radars have challenges for long range and in dense clutter multipath due to limitations of EIRP & SNR.
- A hybrid beam steering + MIMO imaging radar is presented:
  - Compact size and highly integrated
  - Analog steering in elevation + digital MIMO in azimuth
  - Scalable based on AiP modules
  - High EIRP & SNR
  - Excellent RF performance

Acknowledgements

- The work is presented on behalf of the Metawave technical team: *Andrew Bonthron, Ken Carroll, Asher Farooqui, Brian Moore, Ray Haynes, Safa Salman, Hamed Holisaz, Neda Bathaei, Rick Heckler, Lance Kuo, Tony Nguyen, Michael Nilsson, Viktor Novozhilov, David Kendrick, Edmond Megerdichian, Ivan Rodionov, Edward Leonard, Eric Nguyen, Faiz Rahman, Khai Trinh* and *Surya Satyavolu*.