We2B-5

A 220 GHz Code-Domain Focal-Plane Imaging Radar with 0.78 Degree Angular Resolution for Automotive Applications

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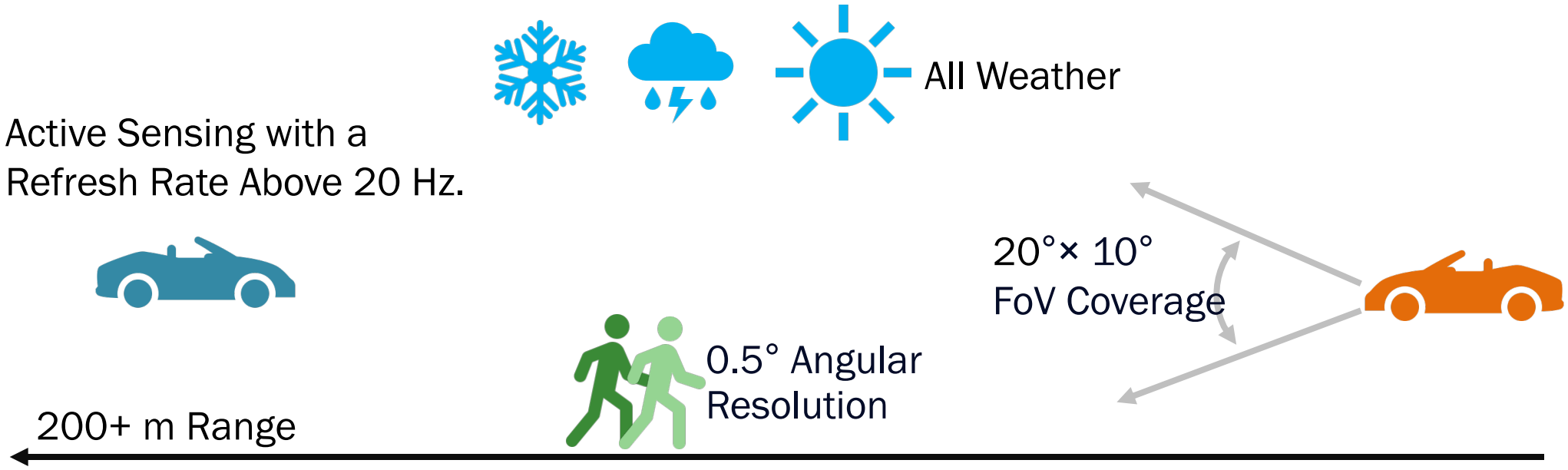
Outline

- Introduction
- Proposed System Solution
- Block Implementation and Measurement
- System Verification
- Conclusions

Requirements for Automotive Sensors

Future automotive applications require weather-robust, high angular resolution, wide spatial coverage, active imaging sensors at mm-wave frequency.



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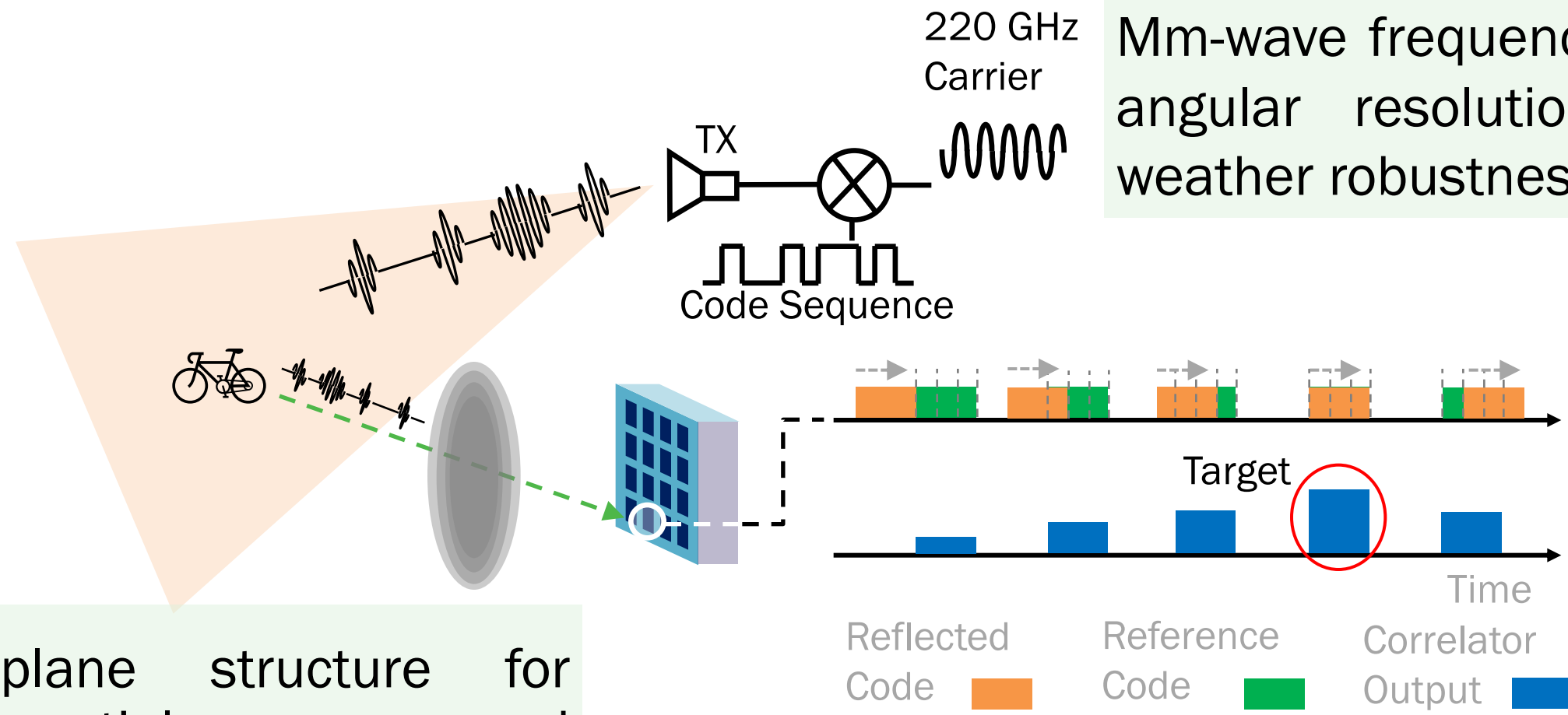
Proposed Solution

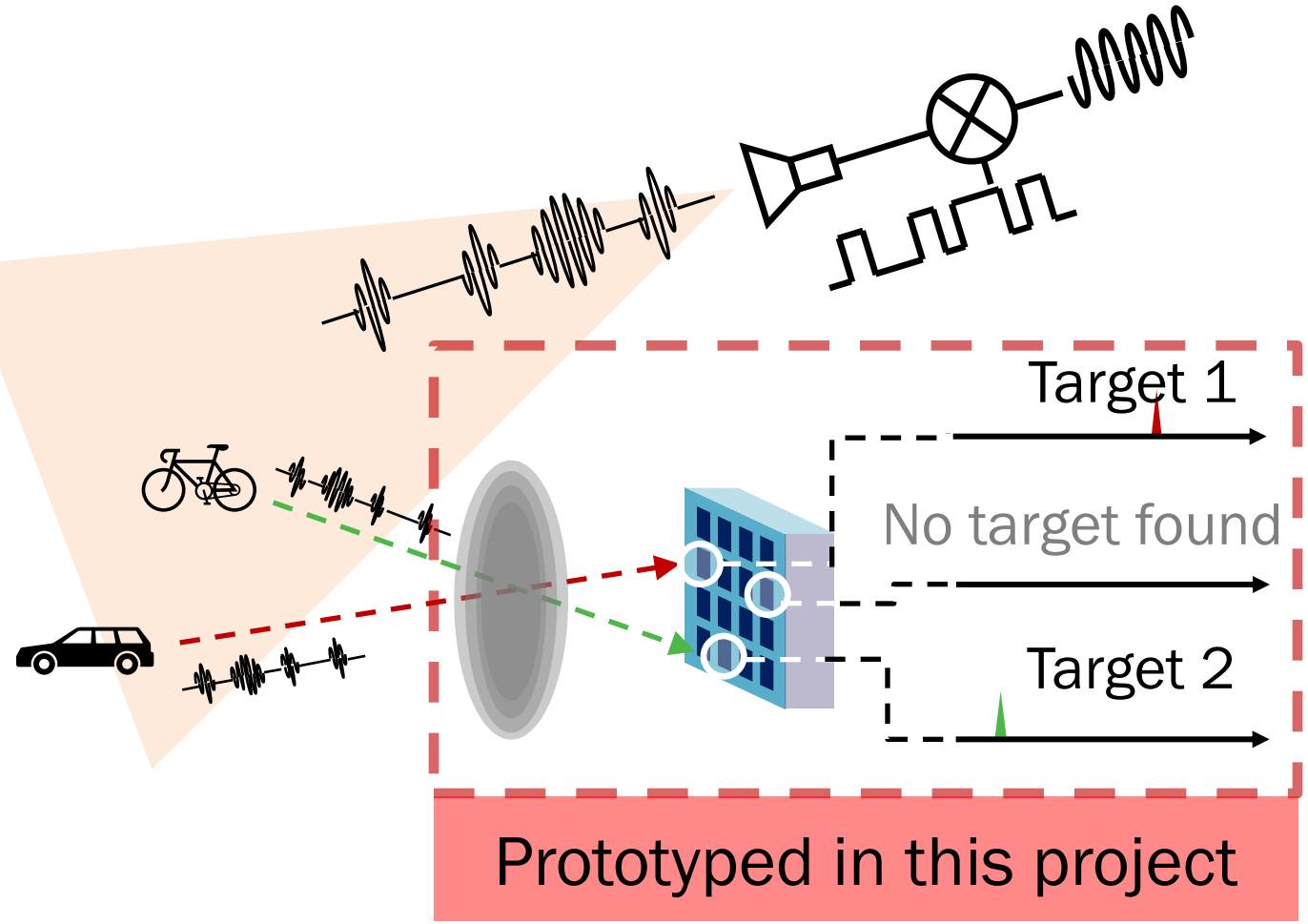


Mm-wave frequencies for angular resolution and weather robustness.

Focal-plane structure for wide spatial coverage and AoA extraction.

Coded OOK waveform for range extraction.

System Overview



- The receiver consists of a plastic Fresnel lens and a CMOS imaging array.
- During each measurement instance (subframe), the TX sends a coded pulse waveform.
- The reflections from the targets are focused by the lens onto the imaging array, where the pulses are detected continuously.

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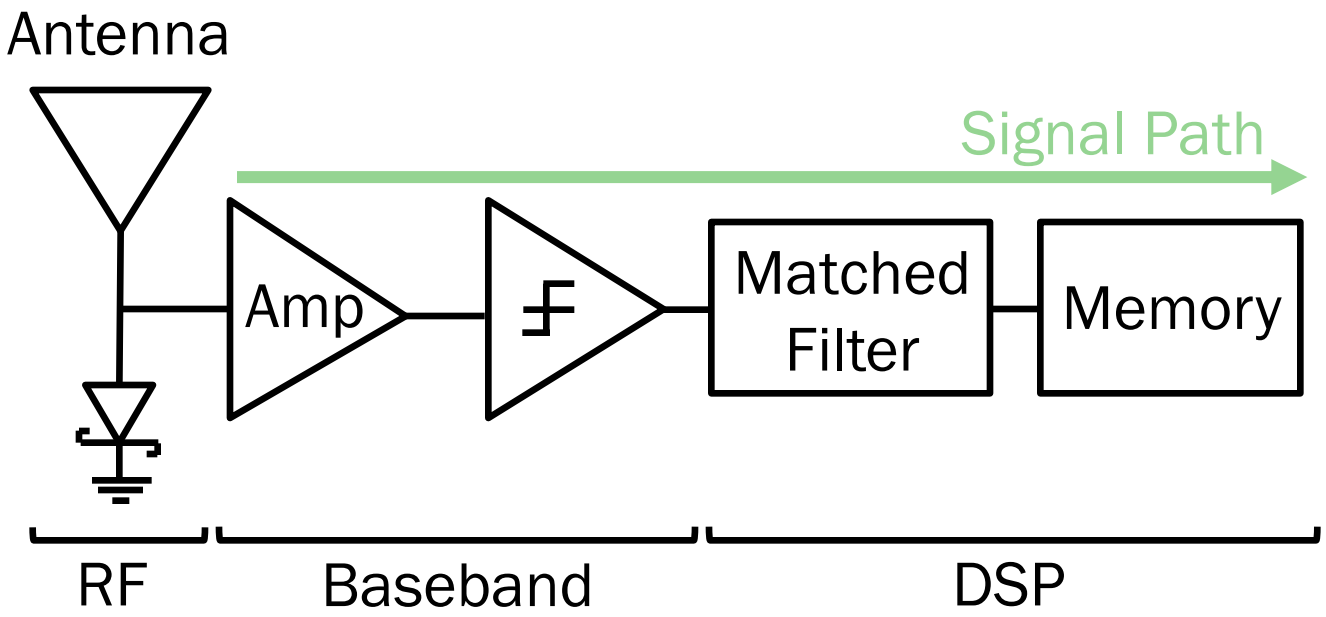
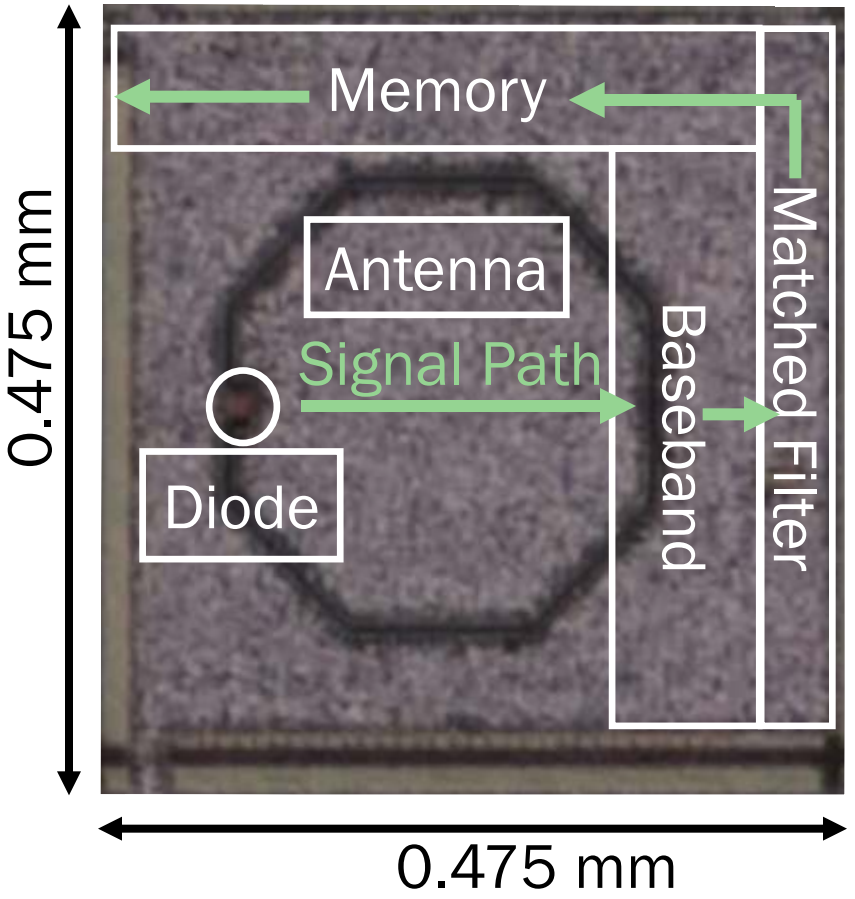
Pixel Implementation



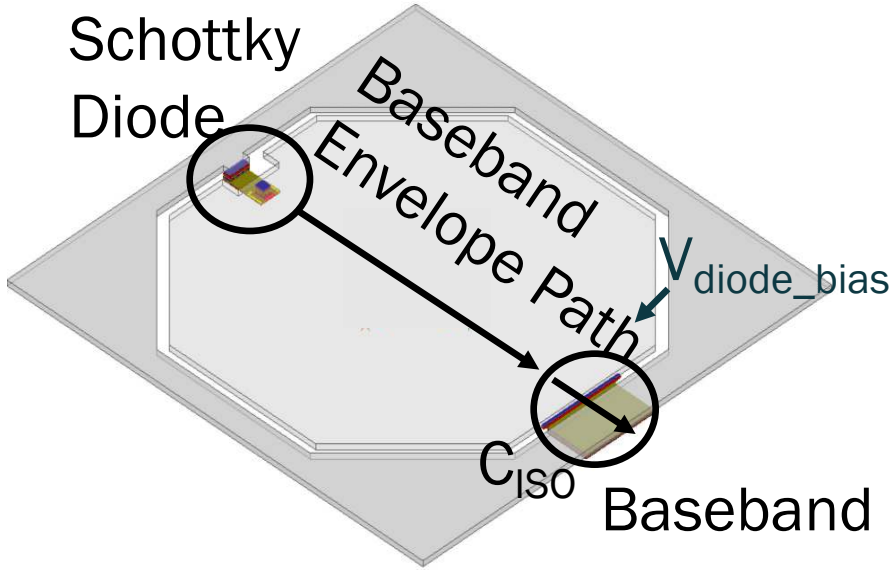


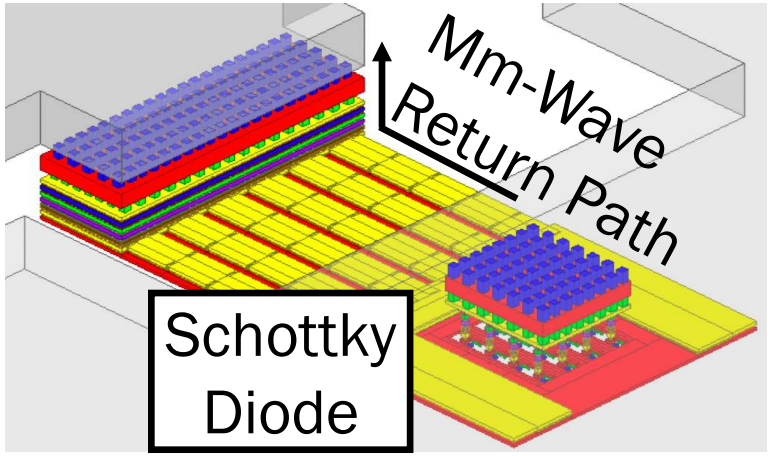
- Each pixel contains a RF/baseband front-end and a digital back-end.
- Fabricated in a 65 nm CMOS process.

RF Implementation

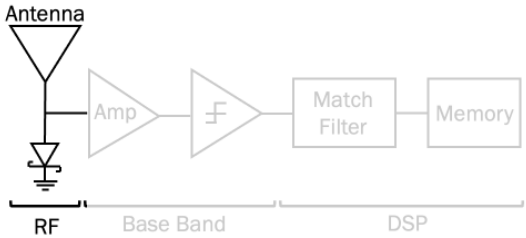
An antenna and a Schottky diode are used for envelope detection.

- Slot ring antenna is implemented using top metal layer.
- C_{ISO} is codesigned with antenna to provide diode matching.
- C_{ISO} also blocks diode DC biasing as well as 1/f noise.



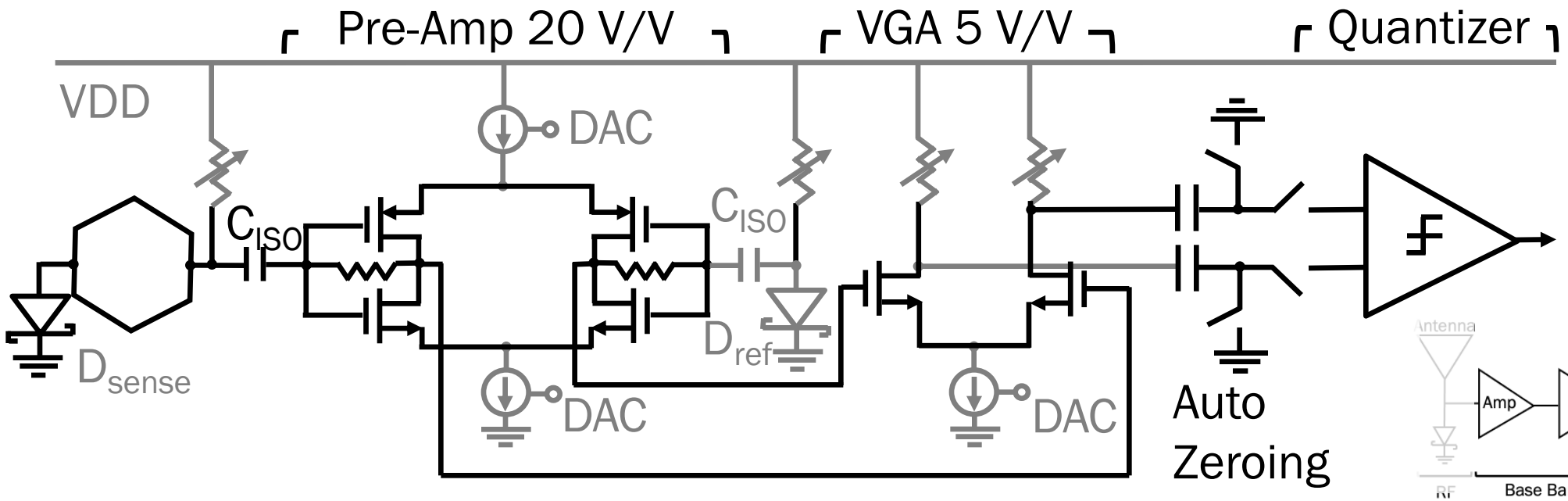


- Diode formed by 16 Schottky contacts.
- Forward biased with measured cutoff frequency of 650 GHz.

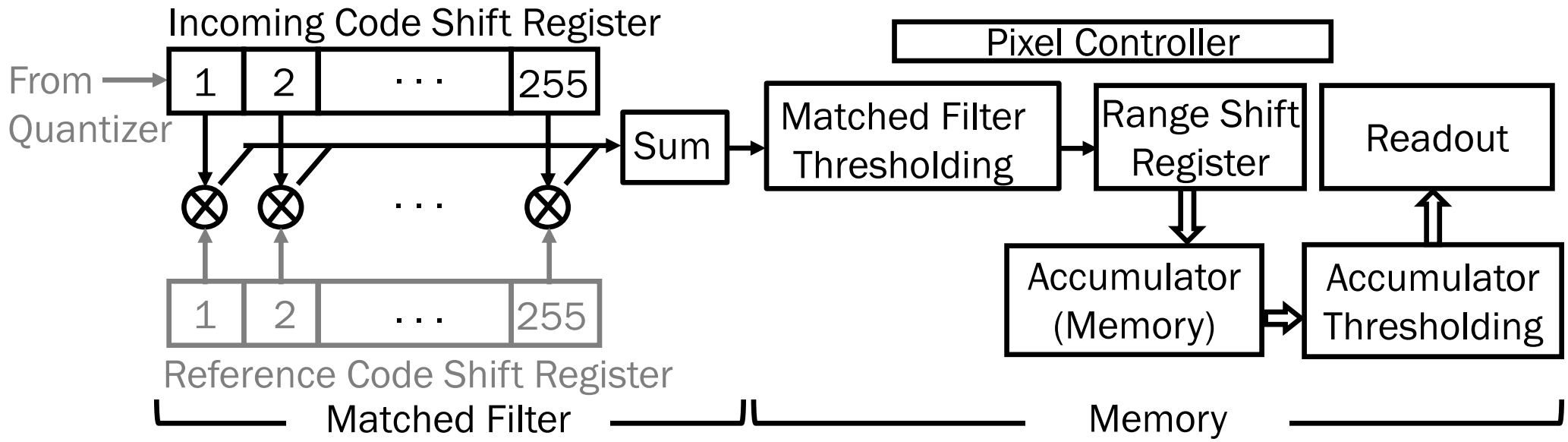


Baseband Implementation

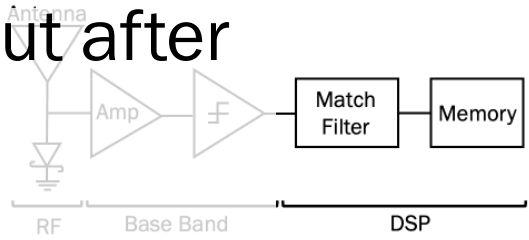
- Pseudodifferential voltage pre-amp is used for digital noise rejection.
- VGA is used to reduce the signal injection from the quantizer to the pre-amp.
- Auto-zeroing is used for offset cancellation.
- StrongARM comparator is used as the quantizer for code reconstruction.



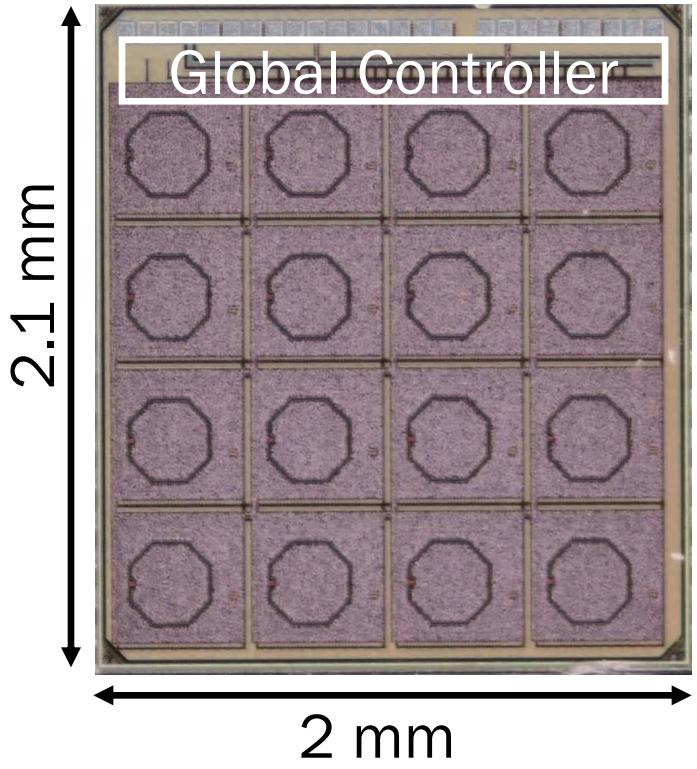
DSP Implementation



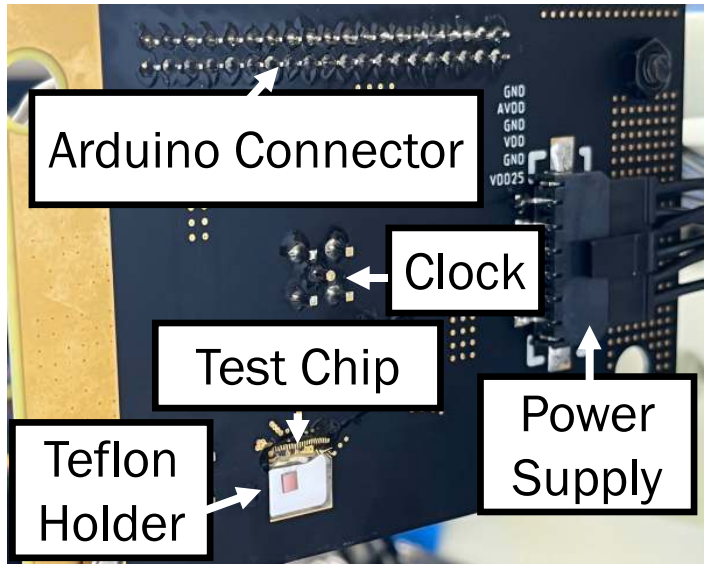
- A 255-bit XNOR based matched filter is chosen for ToF extraction.
- Two layers of threshold control are implemented for false alarm tuning.
- The detection result is stored in an accumulator and read out after each frame.



Array Implementation

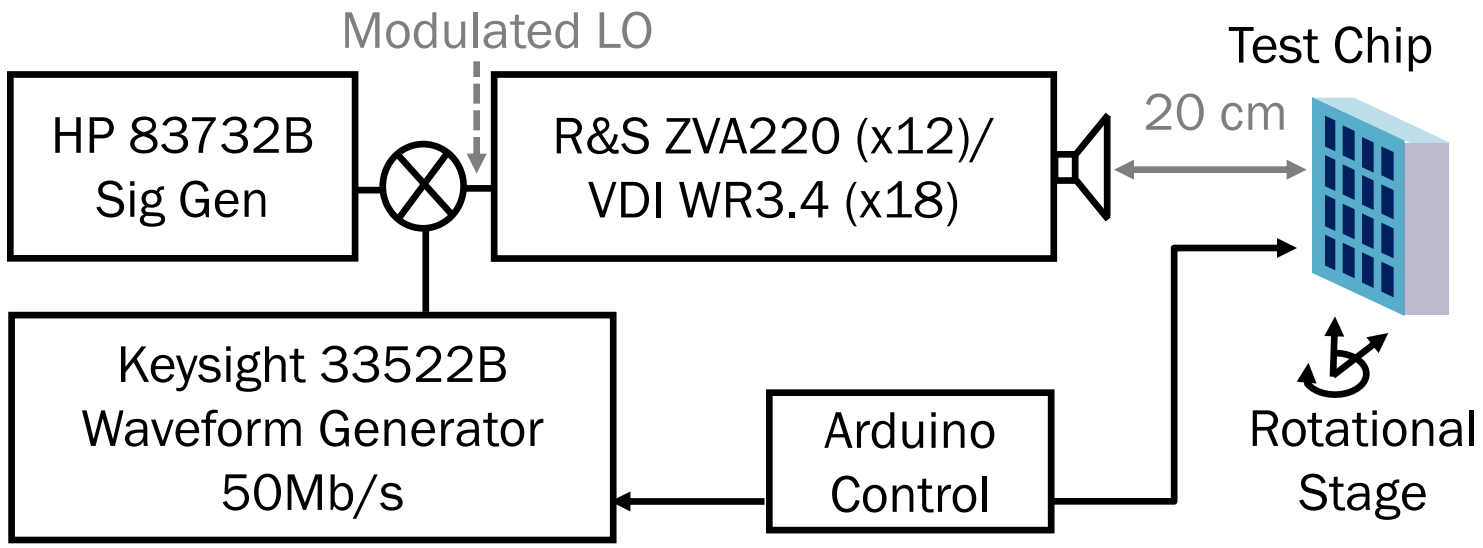


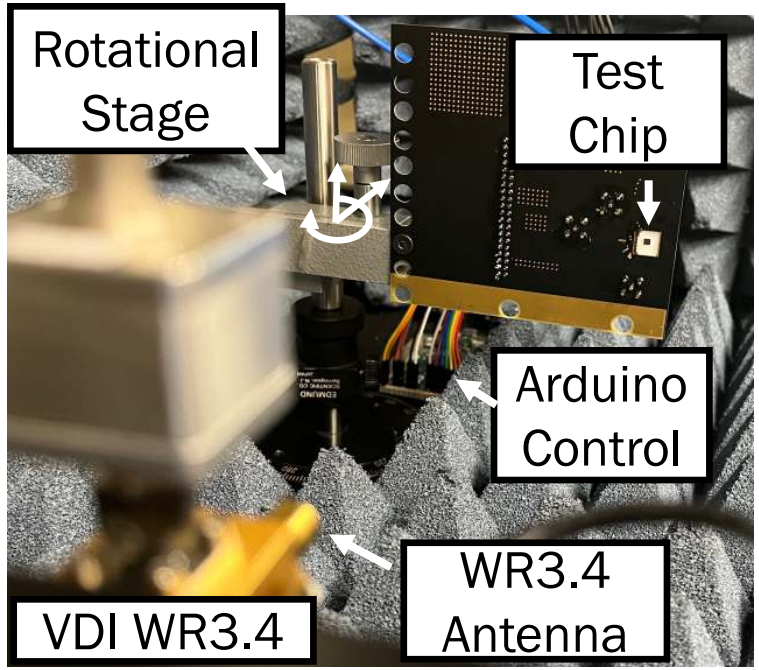
- 19 mW total power consumption at 50 MHz clock frequency:
  - RF/baseband: 9 mW
  - Digital/memory: 10 mW
- The global controller manages readout, controls timing, and selects the pixels under test.



- The test chip is mounted on a Teflon holder and wirebonded to immersion gold-coated pads on the FR4 test board.

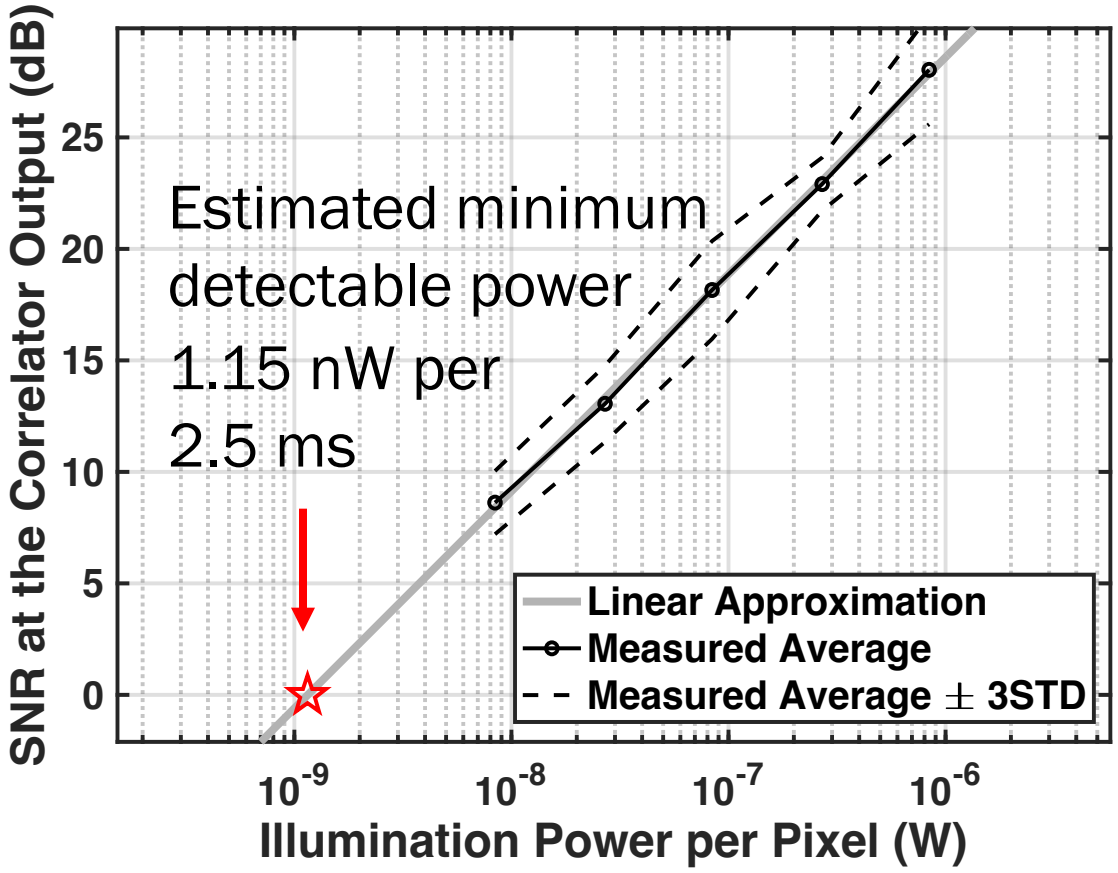
Array Testing Setup



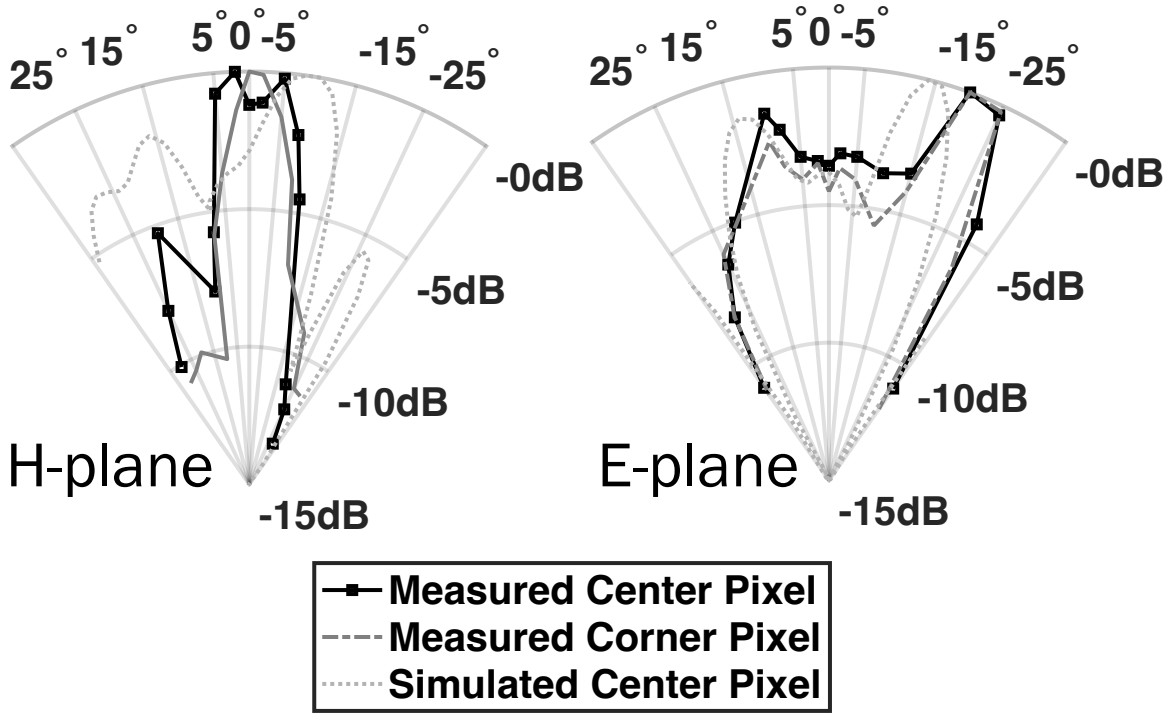


- All measurements are characterized at the correlator output with an integration time of 2.5 ms.
- Different input power levels are covered by using two sets of transmitters.
- Antenna beam-pattern is characterized by rotating the test board and measuring the change in SNR at the correlator output.

Measurement Results

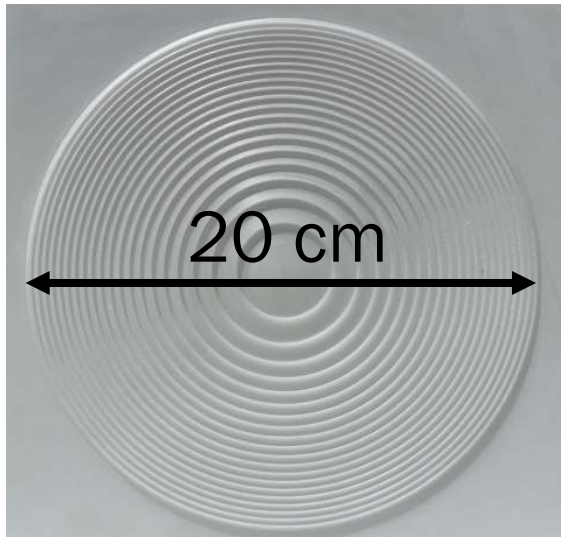


Sensitivity Measurement



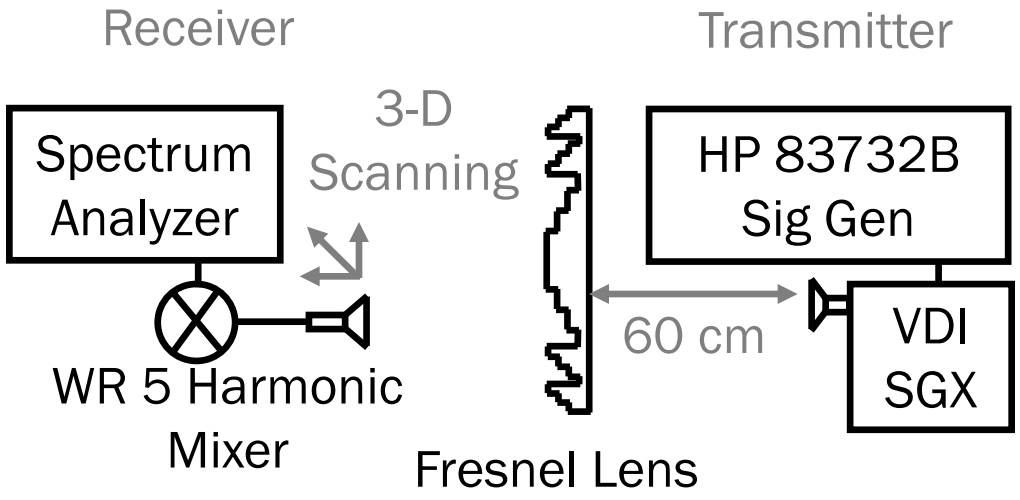
Antenna Beam Pattern

Lens Implementation and Testing Setup

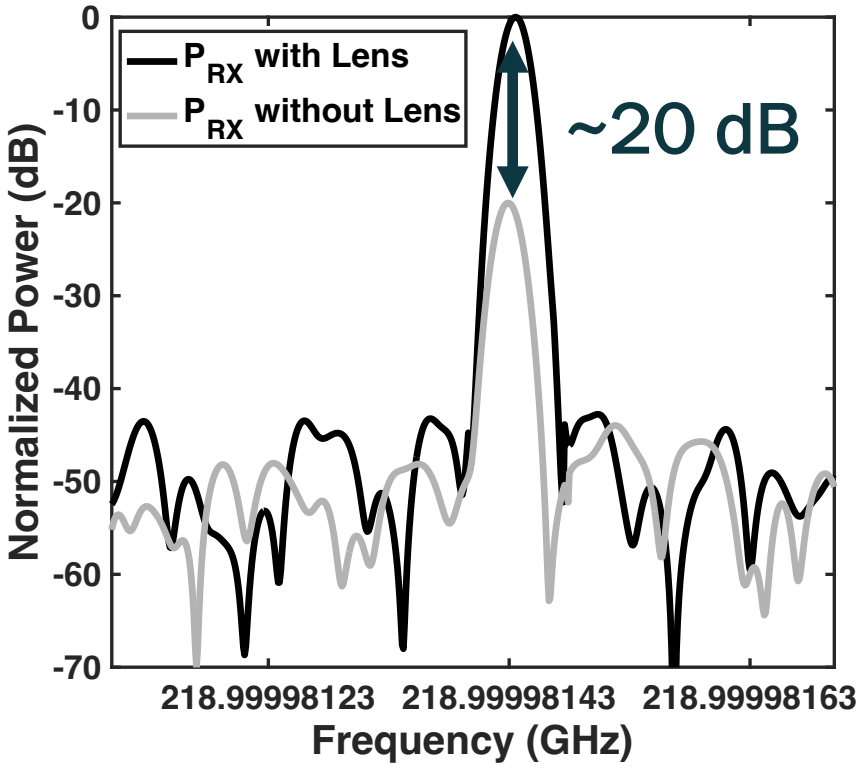


- CNC machined polyethylene Fresnel Lens.
- 20 cm diameter with 0.9 mm engraving depth.
- Designed for 0.5° Rayleigh resolution.

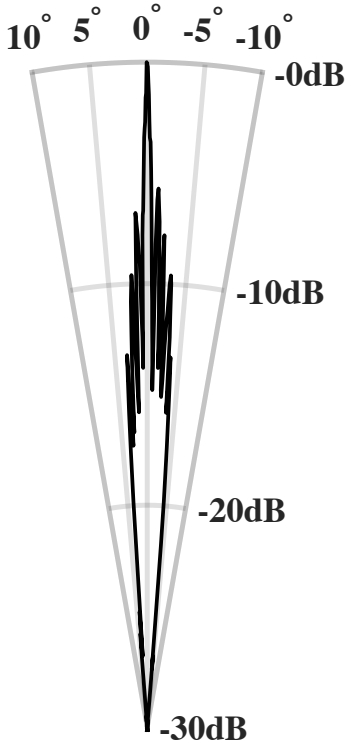
- An off-the-shelf transmitter-receiver set is used for characterization.
- The receiver is mounted on a 3-D scanning stage to measure the lens beam pattern and focal length.
- The frequency bandwidth of the lens is characterized by sweeping the transmission frequency.



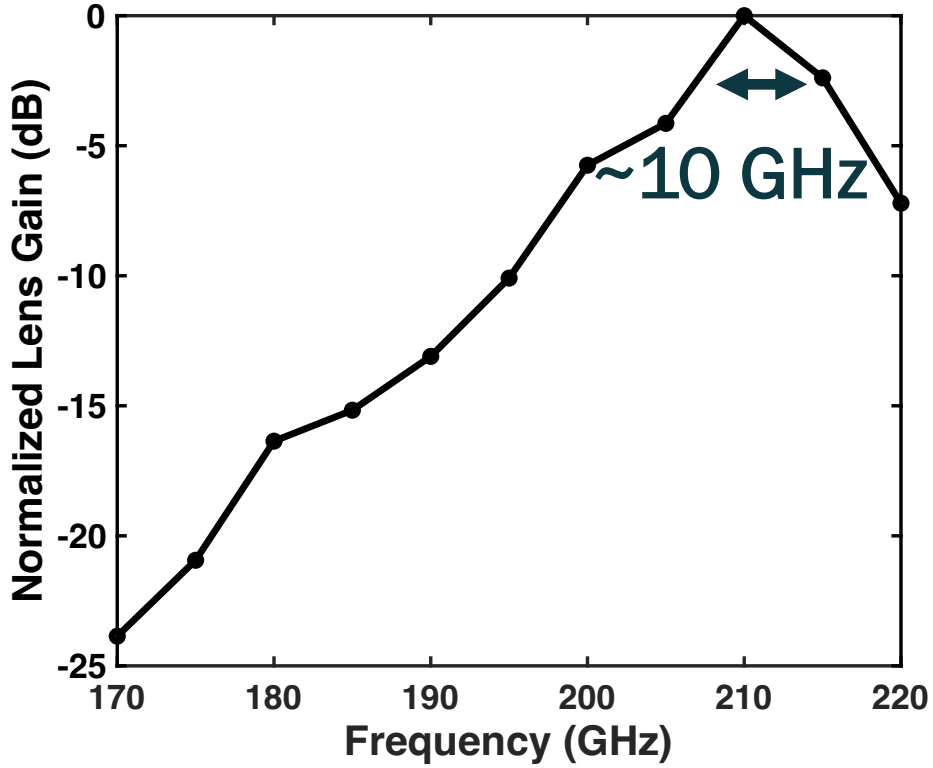
Measurement Results



20 dB
beamforming gain



~0.6°
beamwidth



10 GHz
bandwidth

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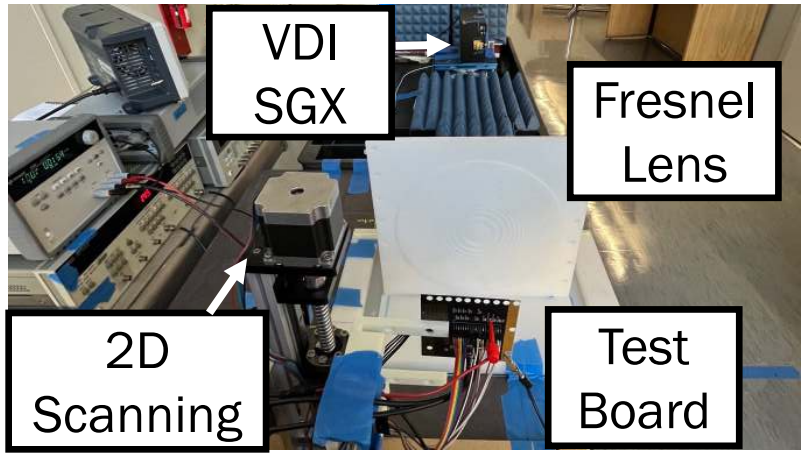
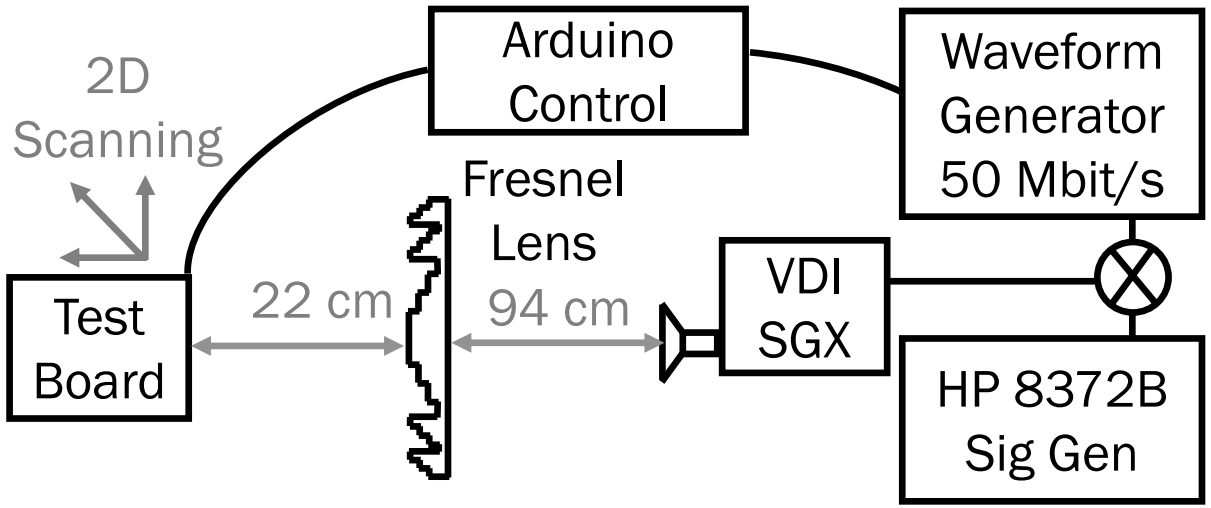
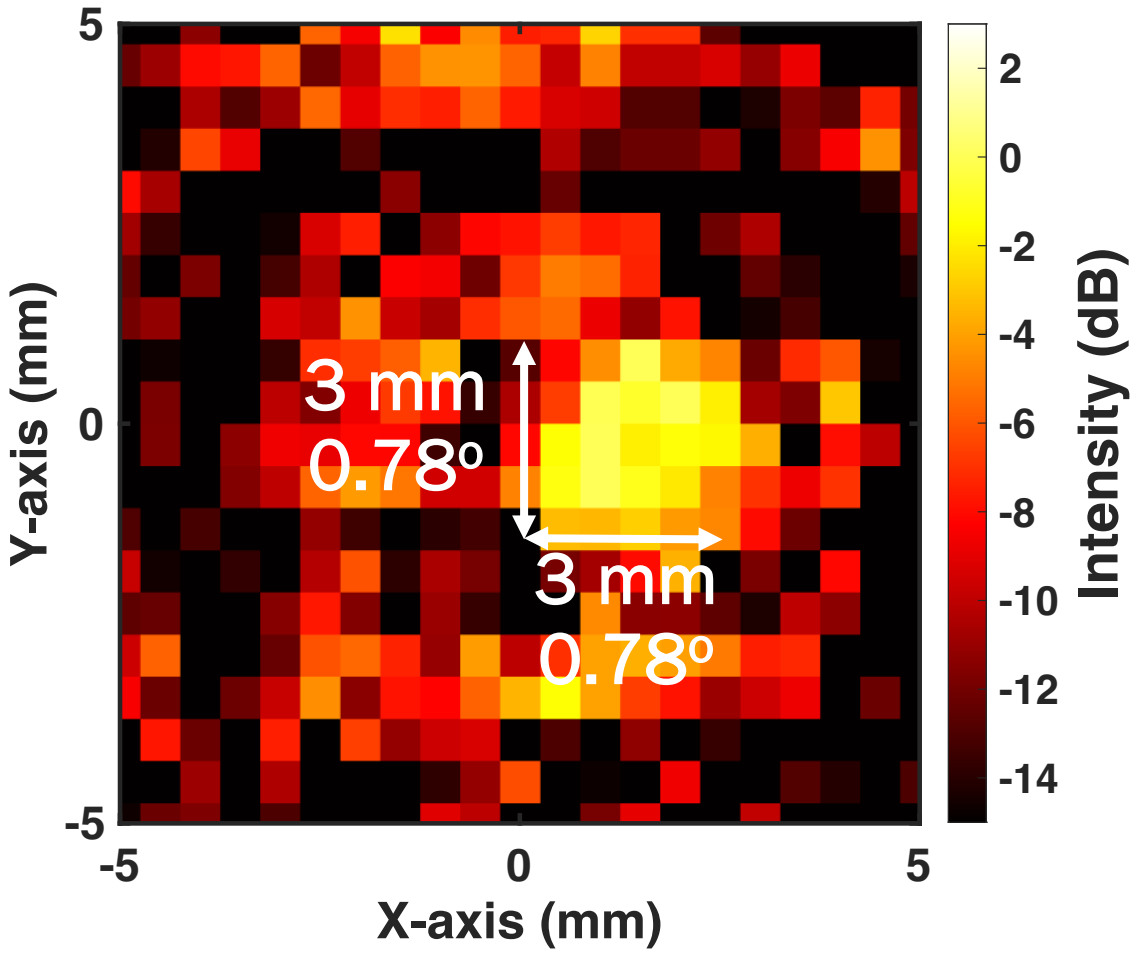
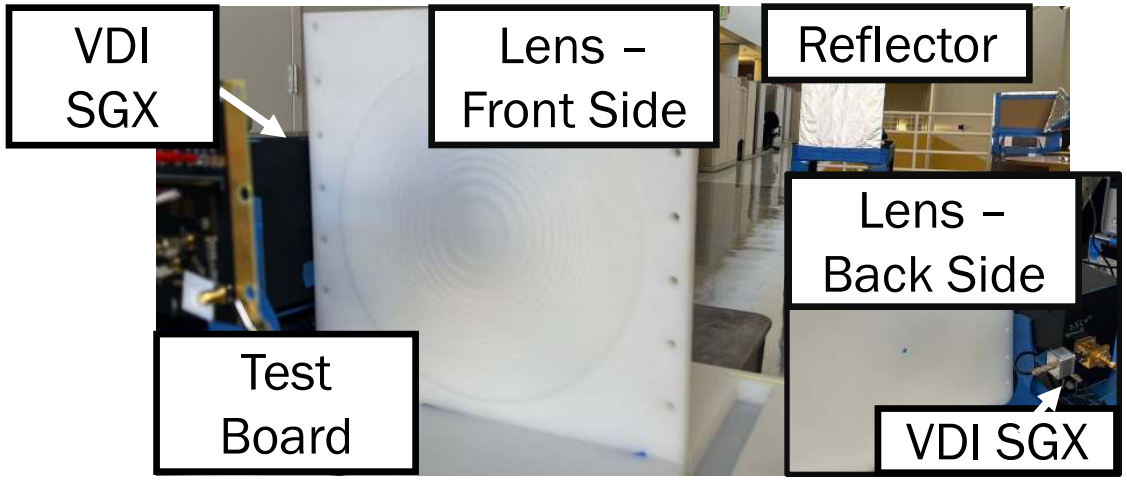
Angular Resolution Verification

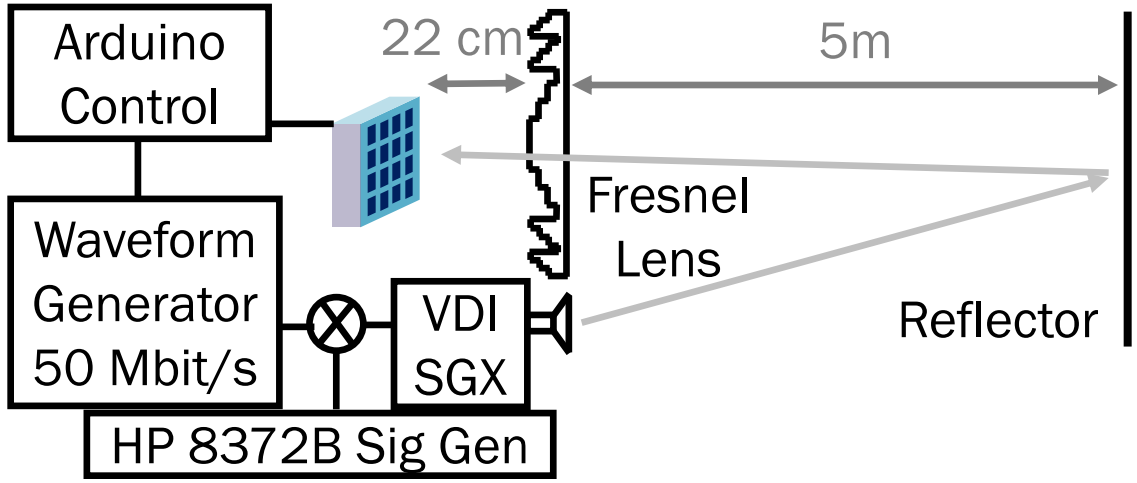


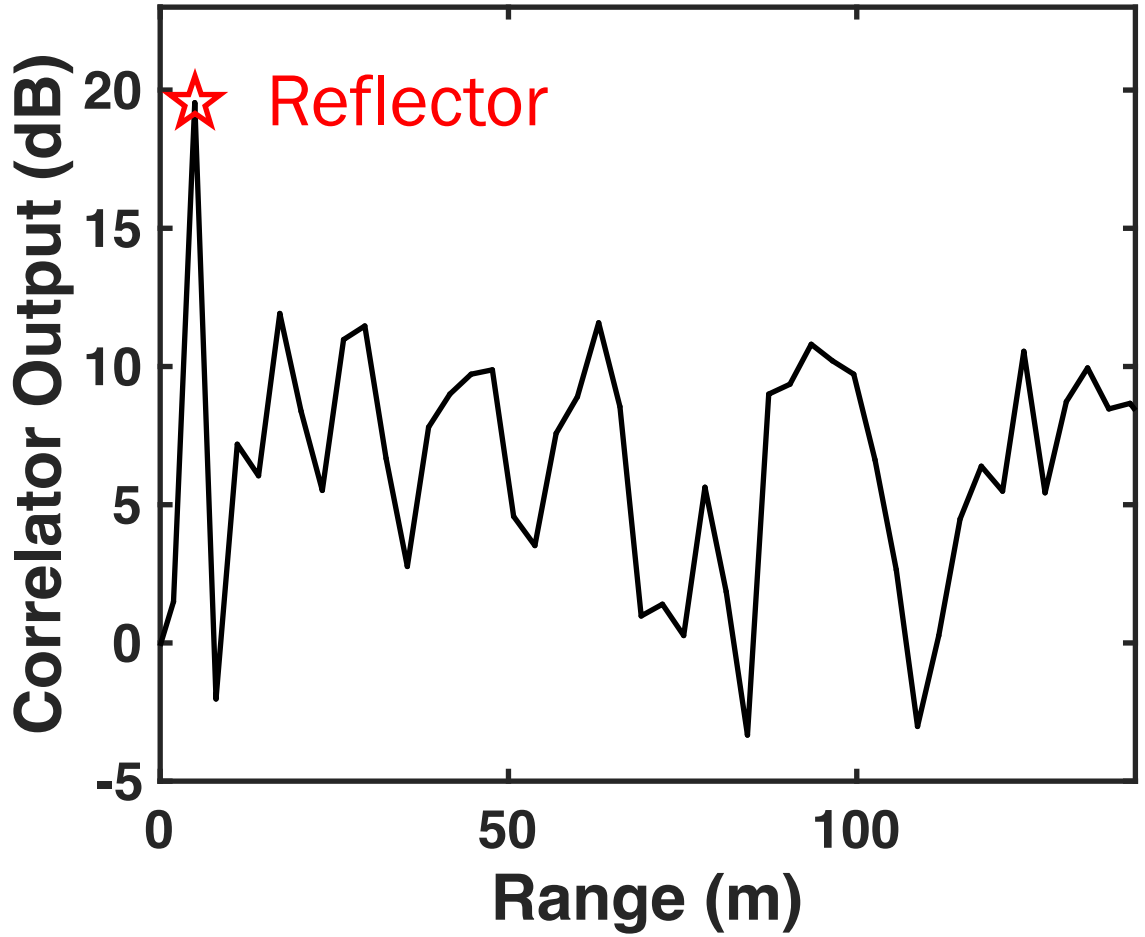




Range Verification







Conclusion

- We present a mm-wave focal-plane imaging system for weather-robust high-angular-resolution automotive sensing applications.
- The system uses 220 GHz coded OOK waveform for range extraction.
- The prototype receiver includes a polyethene Fresnel lens and a CMOS imaging array.
- The whole prototype system exhibits a measured angular resolution of 0.78° at 220 GHz.

Acknowledgment

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Thank You!