Frequency-division multiplexing mm-wave MIMO radars

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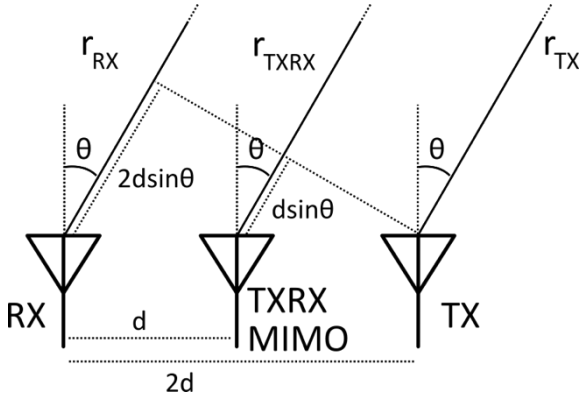
MIMO radar

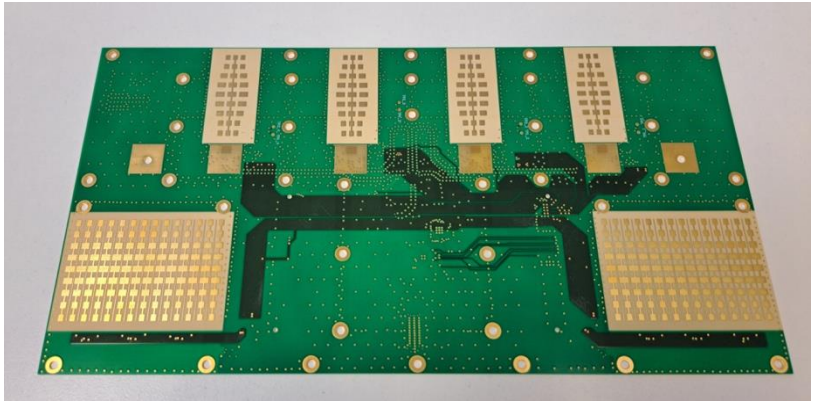
- MIMO radar uses multiple transmit and receive antennas
  - Requires that transmit waveforms from different antennas can be separated at receivers (time, code, or frequency multiplexing)
    - Different from typical phased array radar, where all TX transmit same signal
  - Independent measurement for each transmit-receive antenna pair



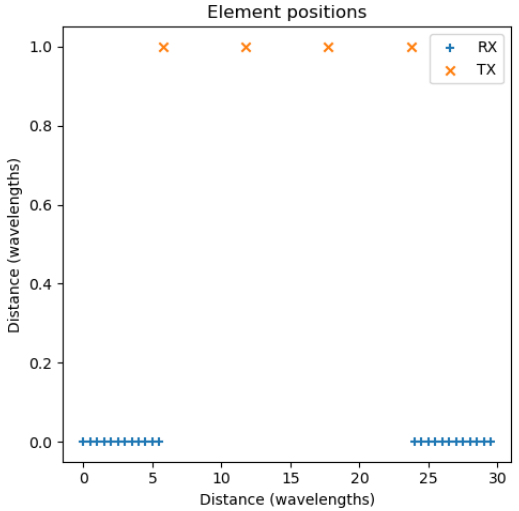
TX-RX antenna pair measures equal distance to transceiver element that is at their midpoint (assuming far-field). Results in independent measurement for each TX-RX pair.

MIMO antenna array

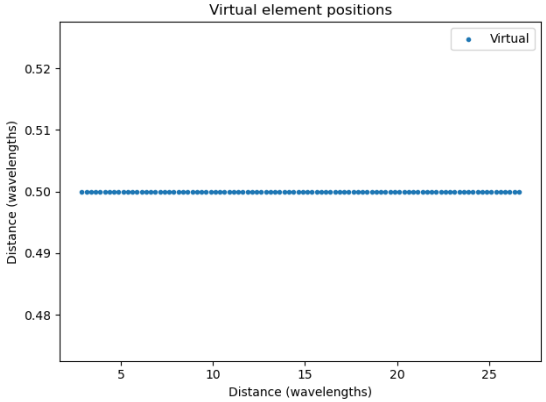
- MIMO array resolution equivalent to receiver array with Ntx*Nrx elements
  - Max 2x better resolution per physical size than equivalent array with one transmitter (overlap of TX and RX antennas)



4TX 24RX MIMO array

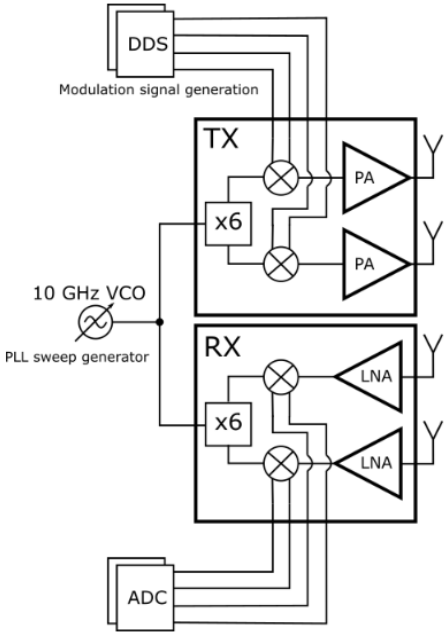


Equivalent to full array with 96 elements



MIMO modulation

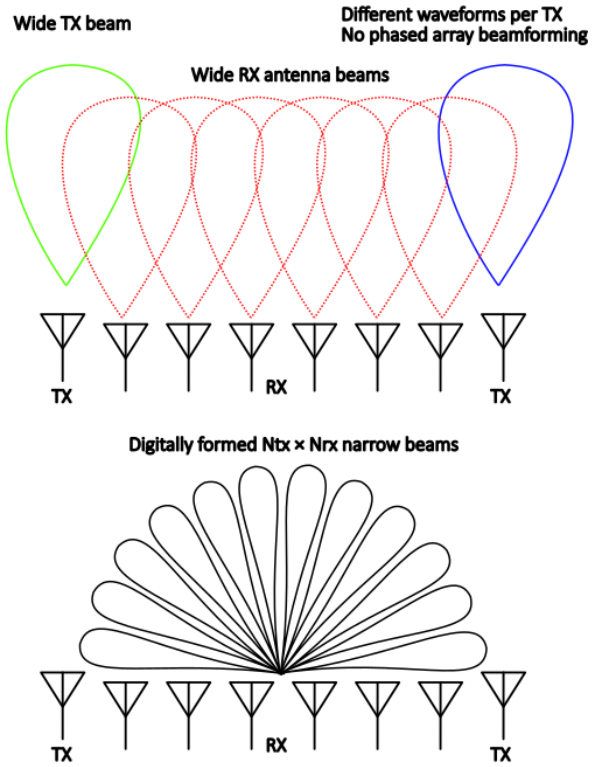
- Time multiplexing
  - Transmit from each TX one-by-one
  - Simple, good isolation, slow
  - Issues with non-static scenes
- Code multiplexing
  - Transmit orthogonal codes from each TX
  - Not compatible with deramp receiver, needs fast ADC
  - Sidelobes due to limited orthogonality and non-idealities
- Frequency multiplexing
  - Each TX transmits at different frequency
  - Range-aliasing if TX signals overlap in frequency
- Other methods also possible



Frequency-division MIMO hardware

MIMO signal processing

- Sample receivers simultaneously
  - Each received signal has reflected signals from each TX waveform
- Demodulate TX signals from each receiver
- Generate Ntx*Nrx measurement array
  - Assign demodulated signals to array corresponding to virtual element locations
- FFT to generate radar image



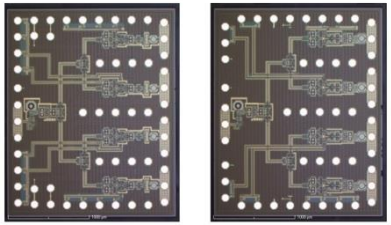
MIMO tradeoff

- Modulation needs additional hardware
  - TX modulators. More data -> needs faster hardware or longer measurement time.
- No antenna gain from TX beamforming
  - TX antennas have different waveforms. Illuminates whole field-of-view
  - Ordinary phased-array radar transmits same signal at each TX. Generates narrow TX beam and directs more power at that area
  - Hybrid-mode operation possible with suitable antenna array
- Good solution for short range (max few km) radars that need good angular resolution
  - Already in use in automotive radars, airport mm-wave security scanners (usually time multiplexing)

VTT MIMO radars

- Multiple custom MMICs
- 15, 34, and 60 GHz frequencies

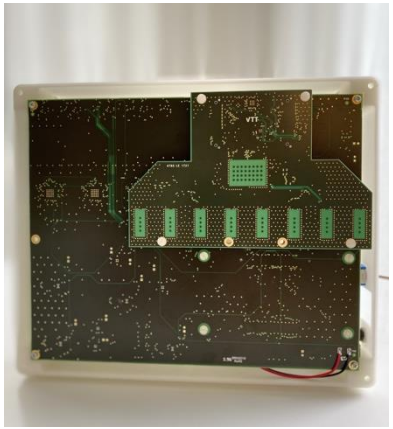
60 GHz SiGe 4ch Radar MMICs



34 GHz, 4TX, 24RX

15 GHz, 4TX, 16RX

60 GHz, 8TX, 8RX

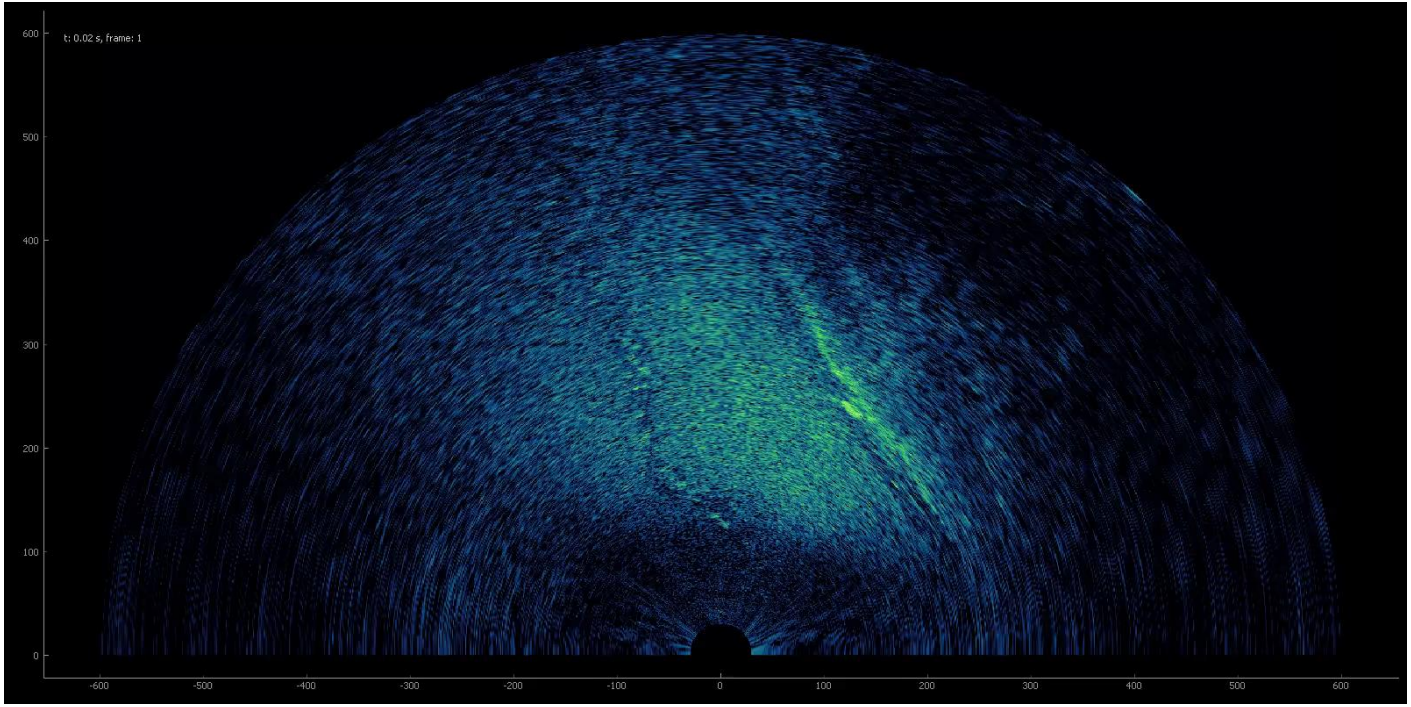


34 GHz, 4TX, 24RX

34 GHz C-UAS radar demo

https://drive.google.com/file/d/1JaE_L9jSQgN7b2Whq39ZEK-ZZDJnpKHD/view?usp=drive_link

Real-time MIMO radar video image - highway



Altitude: 40 m
4TX, 24RX
30 fps update rate

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