Monopulse-based THz Beam Tracking for Indoor Virtual Reality Applications

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Organisation of the Presentation

WORTECS Virtual Reality Use Case

THz communications

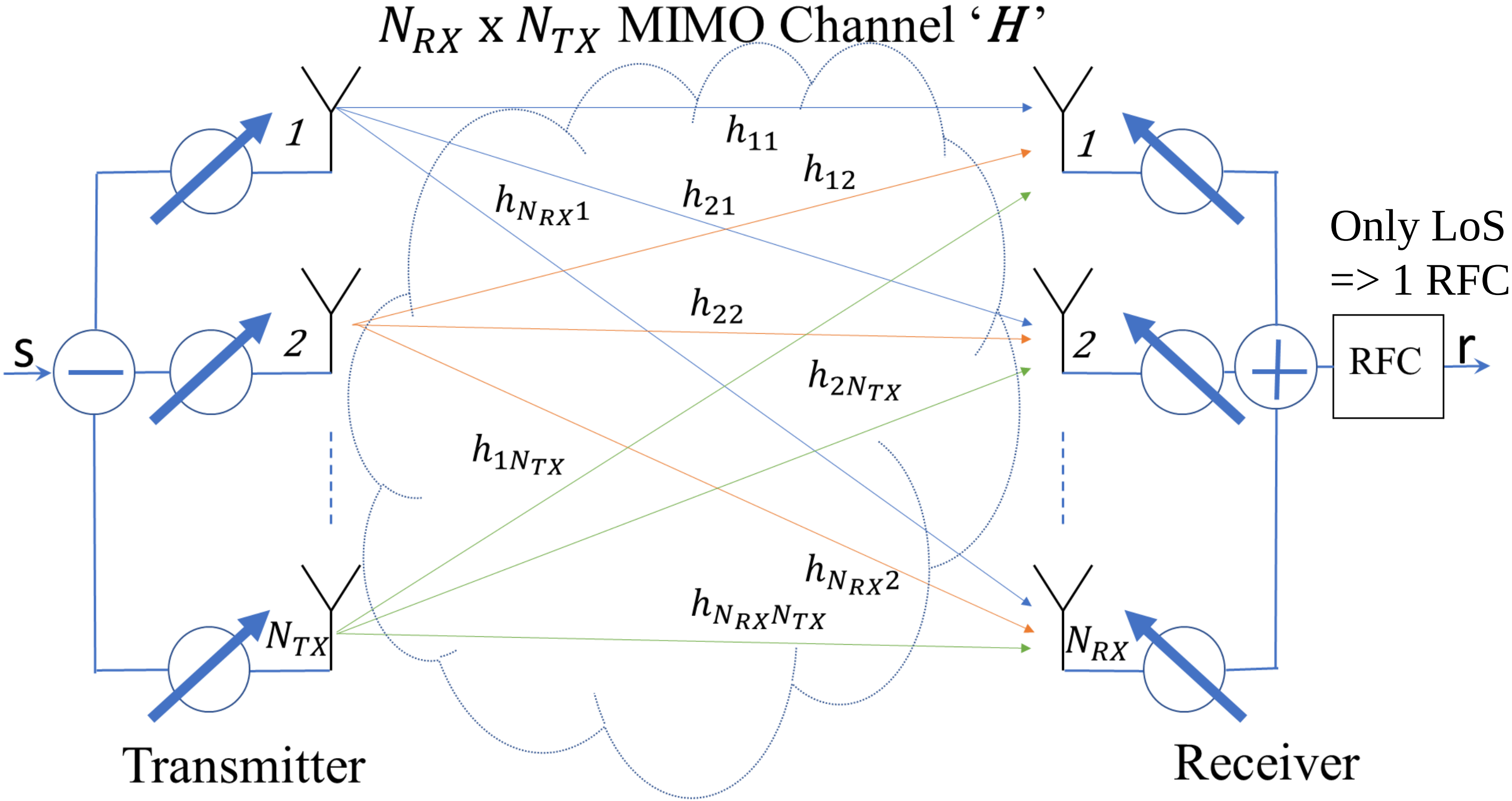
- THz spectrum 0.1 to 10 THz
- Ultra-high data rate radio links → Large bandwidth

  → THz spectrum : Not yet allocated!
- Extremely small wavelength

  → Electrically large antenna arrays in small form-factors
- Raised noise floor, limited EIRP, and propagation conditions

  → only a few radio paths

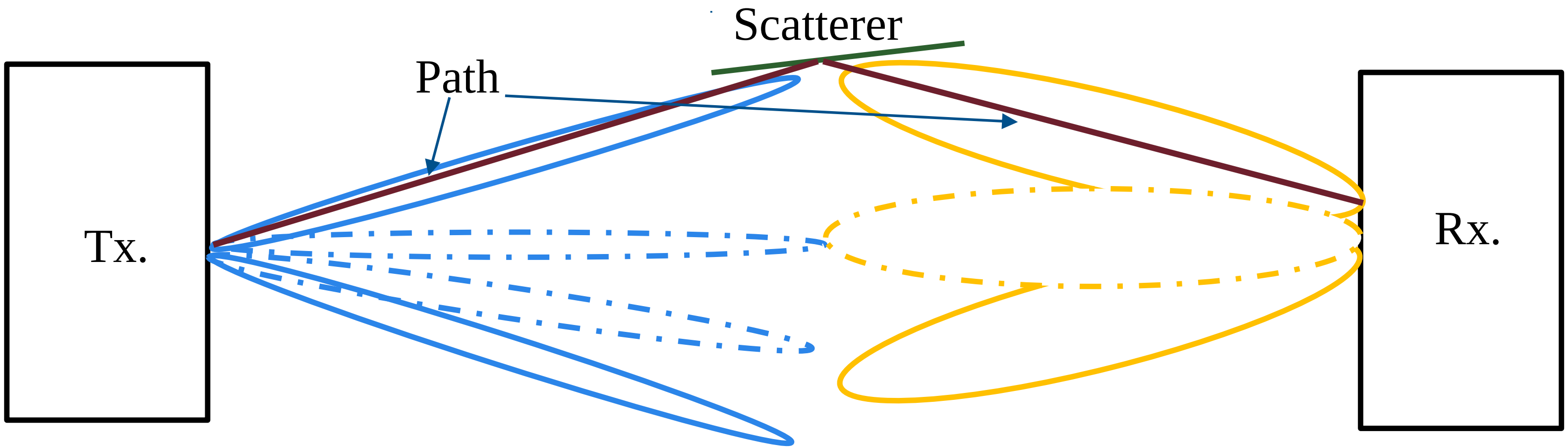
Sparse MIMO Channel



Only LoS path
=> 1 RFC

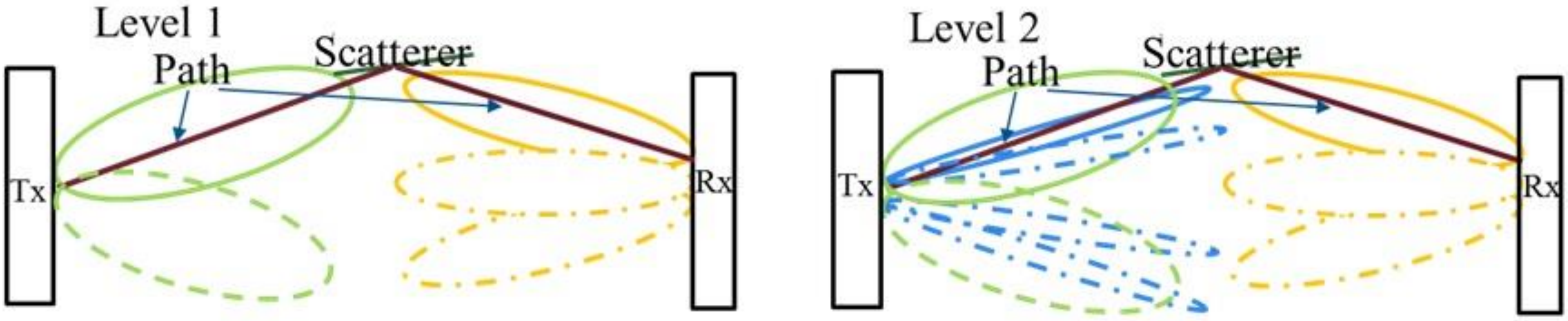
Channel learning in Beamspace: RF Beam Training

- Sparsity reduces the problem of channel learning to RF beam training.



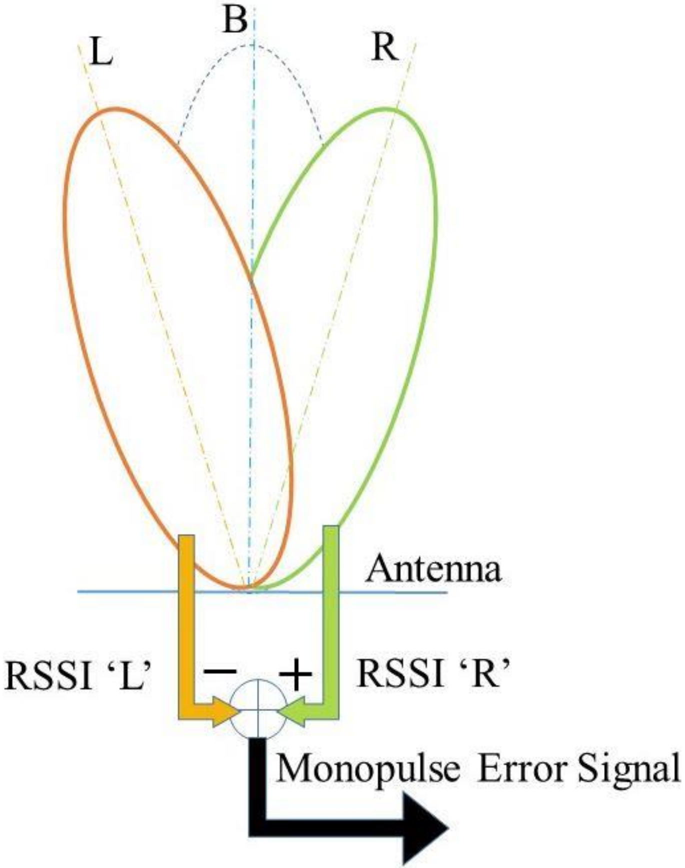
RF Beam Training SOTA

- Exhaustive RF beam training
- Multi-level RF beam training



- Significant overheads and losses
- Use these overheads instead for payload data comms. → Beam tracking

Monopulse-based Beam Tracking



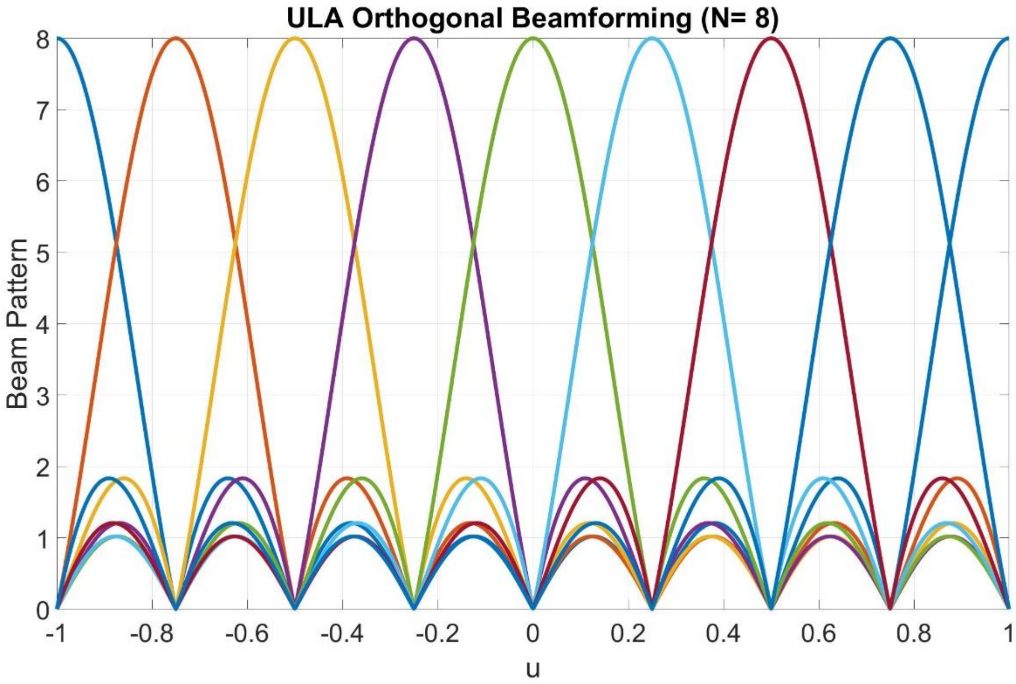
- ~~Kalman-filter based tracking~~ – Needs feedback
- desirable to avoid feedback for resource savings
- Amplitude-comparison monopulse angular tracking
- Uses simultaneous lobing for AoA error generation→ No feedback→ For systems with > 2 RFCs, lower overhead even than sequential lobing & no extra hardware requirement.

Tracking Requirements for VR

- User mobility : 4 kms/h
- User movement over plane surface
- Angular tracking needed only in 1D azimuthal axis
- AoA, AoD, and channel gain are inputs to beam tracking process from the results of RF beam training operation
- Discrete tracking

Design

- 1D → ULA implementation
- DFT beamforming codebook
- HPBW squint in u-space
- Matlab codes as general purpose as possible – using Functions



Mathematical basis for utility of u-space

$$\frac{d}{d\theta} e^{-j\frac{2\pi}{\lambda} d \ sin(\theta)} = -\frac{2\pi}{\lambda} d \cos\ (\theta) \sin\ \left(\frac{2\pi}{\lambda} d \cos\ (\theta)\right) - j\frac{2\pi}{\lambda} d \cos\ (\theta) \cos\ \left(\frac{2\pi}{\lambda} d \sin\ (\theta)\right)$$

(Eq. 1)

$$\frac{d}{du} e^{-j\frac{2\pi}{\lambda} d\, u} = -j\frac{2\pi}{\lambda} d\, e^{-j\frac{2\pi}{\lambda} d\, u}$$

(Eq. 2)

Pseudocode for Matlab implementation

1. Generate DFT codebooks for Tx & Rx.
2. Pass beam search o/p as i/p for beam tracking.
3. Generate MIMO channel matrix based on AoA, AoD, and gain.
4. Calculate error output of monopulse comparator.
5. Select next right / left beam.
6. Iterate steps 4 & 5.

Conclusions

- ➢ THz RF/IF beam tracking requirements for indoor VR/AR applications have been identified.
- ➢ Monopulse-based beam tracking implemented in Matlab, with discrete beam MRAs.
- ➢ No feedback → a minimum overhead solution, overheads lower than sequential lobing.
- ➢ Beam tracking tested manually → error reduces to zero in a few iterations and track is maintained consistently.

Next step:

- ➢ Ideal phase-shift values in Matlab DFT codebooks, in practice digitally-controlled phase-shifters → only discrete phase-shift values feasible → an impact analysis and validation of quantized phase values is an interesting future work with practical relevance.

Thank you for your attention!

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