Electrically reconfigurable random THz wavefronts for rapid localization sensing

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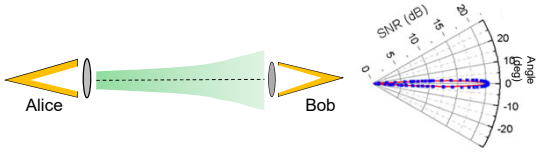
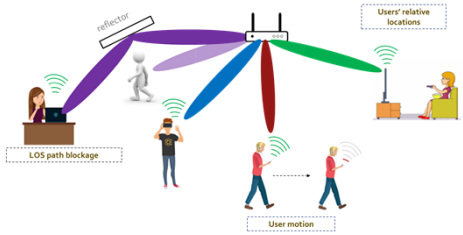
THz links are directional: both a blessing and a curse

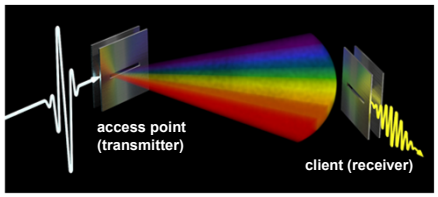


Challenges with THz links: mobility, blockage, scalability

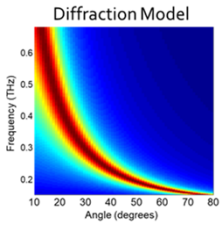


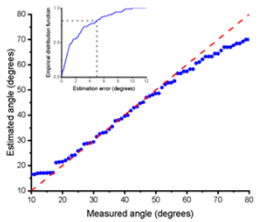
A crucial aspect of making all this work:
rapid sensing of receiver location

One idea: broadband excitation of a leaky-wave antenna (LWA)



"Single-shot link discovery for terahertz wireless networks," Y. Ghasempour, et al., *Nature Communications*, 11, 2017 (2020).

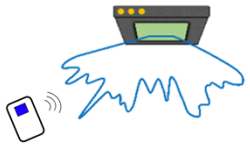




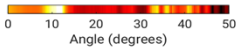
Mean estimation error: ~2°

This is limited by wavefront angular correlation.

Step 1: Encoding location using random wavefronts



Transmitter broadcasts a random amplitude (and phase) vs. angle

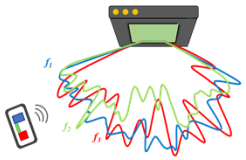


Receiver compares measured signal against a codebook

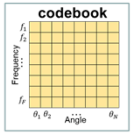
$$\theta^{estimated} = \min_{\theta \in \Theta} \left\| h^{meas} - h(\theta) \right\|_2^2$$

Key advantage: this is scalable in both time and frequency!

Step 2: Scaling in frequency: broadband random waves



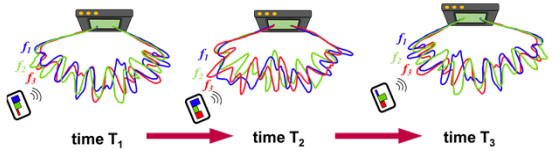
Receiver compares measured signal against a 2D codebook to estimate angle



Transmitter broadcasts a random amplitude (and phase) vs. angle and frequency

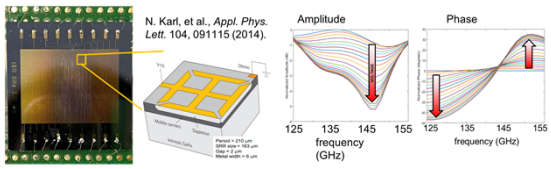
$$\theta^{estimated} = \min_{\theta \in \Theta} \left\| h^{meas}(f) - h(\theta, f) \right\|_2^2$$

Step 3: Scaling in time: repeated broadband random waves



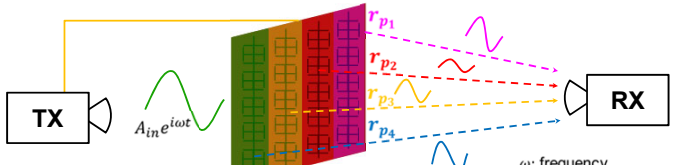
How to implement this?

A multi-pixel reconfigurable metasurface

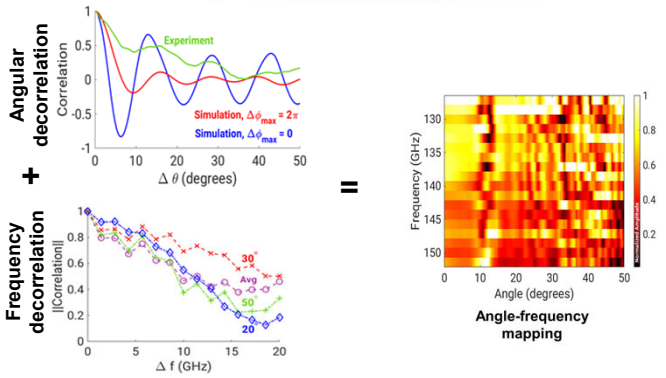


Generating random wavefronts

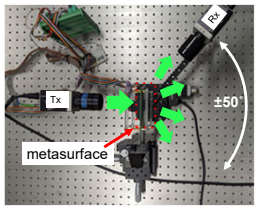
We apply a random voltage to each column of the metasurface

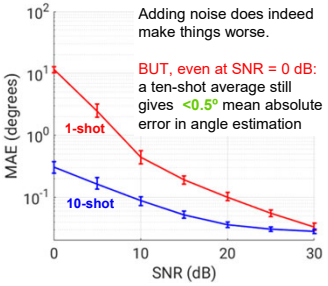


$$E_{RX} = \sum_{p=1}^{P} \underbrace{\frac{e^{i\omega r_p/c}}{r_p}}_{\text{Propagation}} \cdot \underbrace{A_p e^{i\phi_p}}_{\text{Randomize across p}} \cdot \underbrace{A_{in} e^{i\omega t}}_{\text{Source}}$$



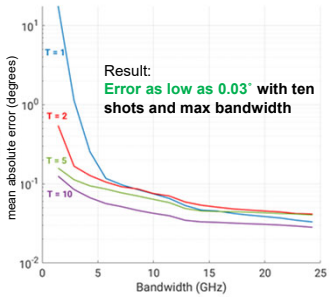
Experimental Evaluation





Adding noise does indeed make things worse.

BUT, even at SNR = 0 dB: a ten-shot average still gives <0.5° mean absolute error in angle estimation



Result:
Error as low as 0.03° with ten shots and max bandwidth

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