mmWall: A Steerable, Transflective Metasurface for mmWave Networks

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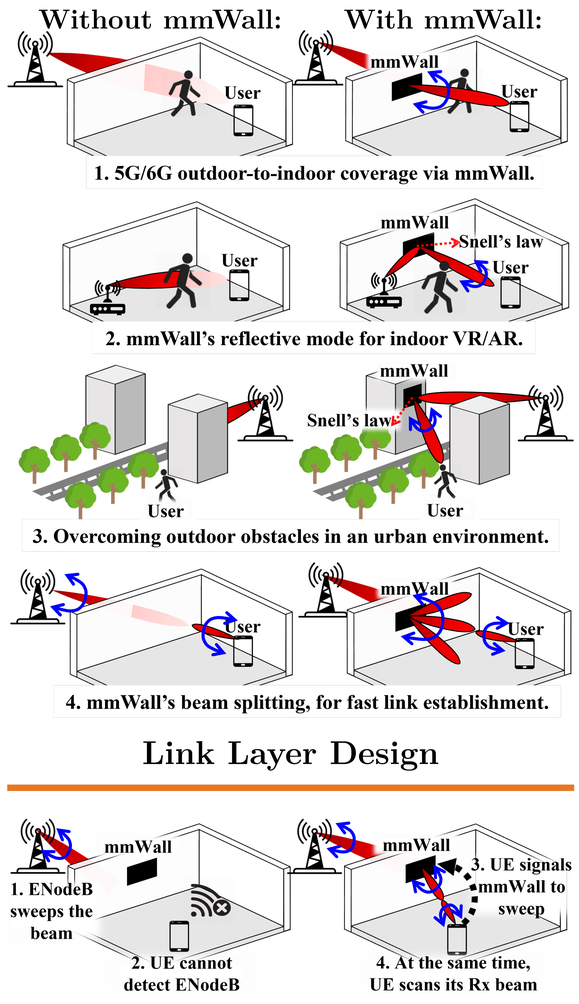
Summary

- While millimeter-wave (mmWave) spectrum enables high spectral efficiency and low latency wireless networks, it is extremely vulnerable to blockage by walls, people, and obstacles.
- **mmWall** is the first electronically almost-360° steerable metamaterial surface that refracts, reflects, or splits incoming mmWave signals, overcoming mmWave's fundamental challenges.

mmWall's Key Scenarios

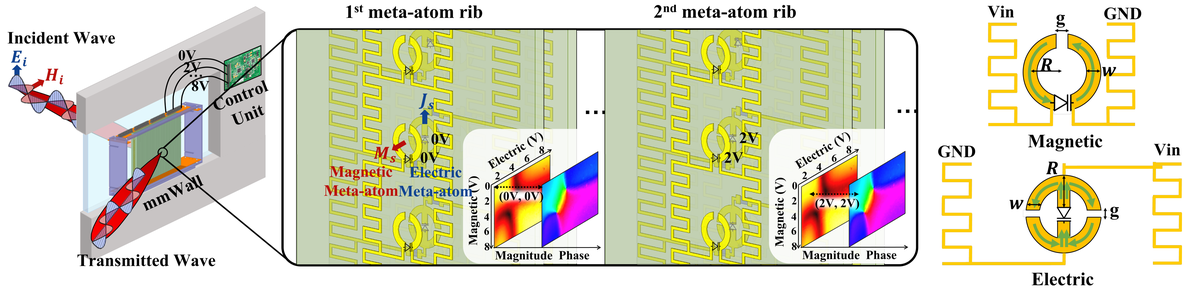


Link Layer Design

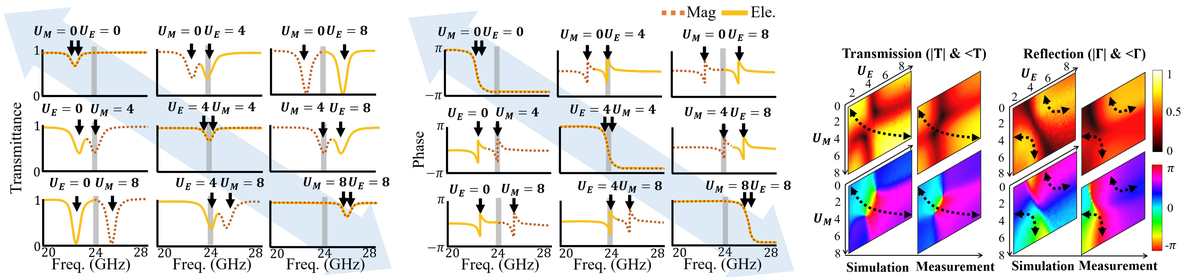
Since BS and mmWall are stationary, alignment then happens between mmWall and UE, only.

mmWall Hardware Design and Analysis

mmWall's high-level design overview and unit cell design:

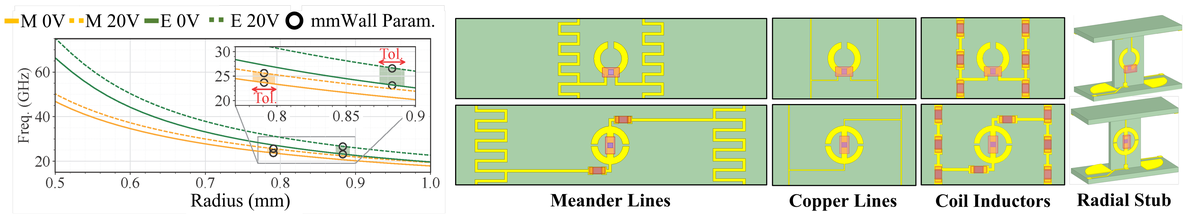


Unit cell response (electric- and magnetic-side voltages U_E and U_M):



(a) Transmission magnitude $|T|$ (b) Transmission phase shift $\angle T$ (c) T and Γ magnitude, phase at 24 GHz.

mmWall design parameter sensitivity analysis and control circuitry design:



(a) Scaling mmWall to mmWave freq. (b) Biasing networks

Hardware Prototyping and Implementation

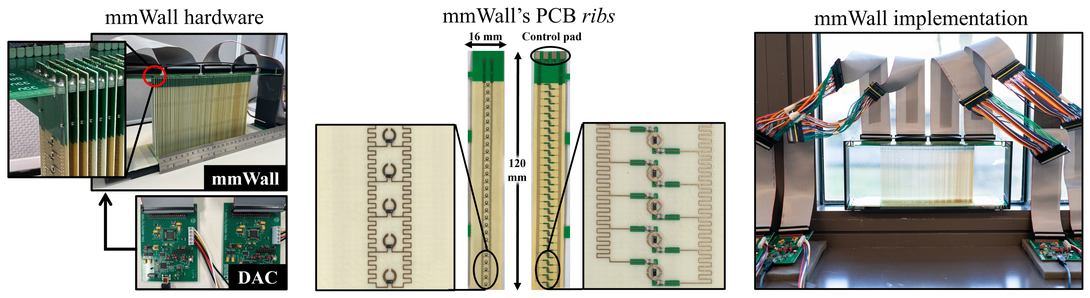
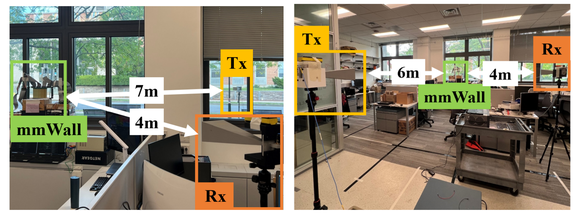


Figure 4: 120 × 197.6 mm hardware prototype. Meta-atoms are fabricated on a rib made of Rogers 4003C PCB board. There are 76 ribs, each consisting of 28 vertical meta-atoms. DACs independently control all cells of every mmWall rib.

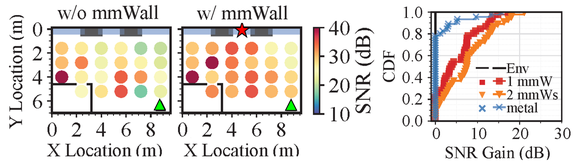
Evaluation



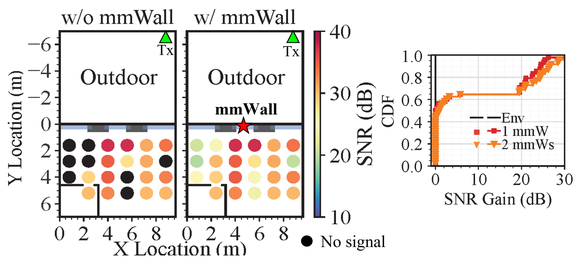
(a) Outdoor-to-indoor. (b) Indoor-to-indoor.

Our empirical results show:

- mmWall **improves room corner coverage** by up to 15 dB for indoor-to-indoor. Also, it guarantees 24 dB across all locations (Fig. 6a).
- mmWall boosts SNRs by up to 30 dB for outdoor-to-indoor. While >40% of in-locations experience signal outage without mmWall, **mmWall guarantees all locations outage-free under 64-QAM** (Fig. 6b).



(a) Indoor-to-indoor reflective relay.



(b) Outdoor-to-Indoor transmissive relay.

Figure 6: *Left:* SNR measurements with and without mmWall; *right:* CDF of SNR gains of one or more mmWalls over the best environment path (mmWall ★, Tx ▲, Rx ◯).

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`https://www.usenix.org/system/files/nsdi23-cho-kun-woo.pdf`