Popular Science Summary

Seeing the invisible: Visualizing radio waves in Augmented Reality

Wireless engineers usually study radio waves as tables of numbers. We built an Augmented Reality tool that lets them see the waves instead, drawn as 3D paths through the actual room, viewed through a headset.

Wi-Fi and 5G keep us connected, but the radio waves that carry our data are invisible. When engineers measure how these signals travel through an indoor environment, the result is a table of numbers. Knowing that a signal bounced at 30 degrees after traveling 12 meters tells you little about what happened in the room itself.

Our goal was to bridge that gap by turning the static numbers into a 3D scene a researcher can step inside and explore. The pipeline takes a 3D laser Light Detection and Ranging (LiDAR) scan of a real room and combines it with the recorded signal data. A computer reconstructs the path each radio wave took, labeling it as line-of-sight, single-bounce, multi-bounce, or out-of-bounds (when no intersection was found). The reconstructed paths are then streamed wirelessly to a Meta Quest 3 headset, which overlays them onto the user's view of the room.

The hardest part was spatial alignment: making a ray that bounced off a real wall look like it is hitting that same wall in the headset. Our first version asked the user to calibrate the room by placing their controllers in the corners, but small placement errors caused the virtual rays to misalign. We replaced this manual step with an automatic one. The headset builds its own 3D mesh of the room in real time, and our software aligns the LiDAR scan with the headset's scene mesh to snap the two coordinate systems together and calculate a transformation matrix. Placement errors dropped to one to five centimeters.

The result is a tool that replaces numerical tables with spatial intuition. Researchers can walk through a measured environment and see exactly where each

signal went and what it bounced off, giving them a clearer foundation for designing the next generation of wireless signals.