

# Air-interface innovations for always-on AI at scale

The 6G air interface is being purposefully designed to unlock more value from spectrum for all

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6G Foundry: Explore the next generation of wireless connectivity with Qualcomm Technologies experts.

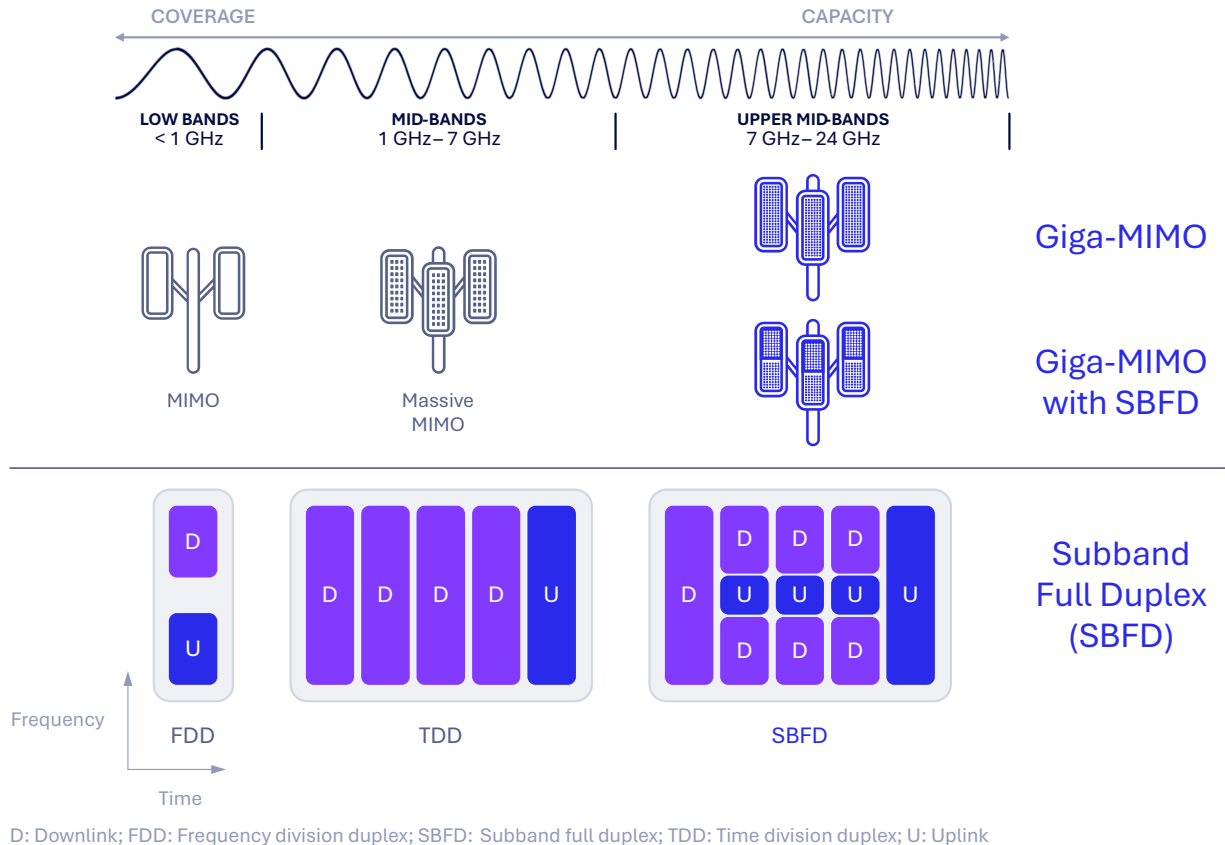
[Read Part 8 — The next air interface for a more capable, connected future](#)

## What you should know:

- [Giga-MIMO](#) unlocks wideband channels in upper-midband spectrum for wide-area coverage with high throughput.
- [Subband full duplex \(SBFD\)](#) increases uplink duty cycles, reduces uplink and downlink communication latency and improves user-perceived throughput and coverage.
- Together, these technologies enable 6G networks that support use cases like always-on AI, immersive XR, autonomous vehicles and integrated sensing, guiding infrastructure, product and spectrum decisions and more for next-generation applications.

## The conversation about 6G begins with familiar building blocks: Multiple-Input Multiple-Output (MIMO) and full duplex technology.

Operating with MIMO increases capacity and reliability by using multiple antennas at the transmitter and receiver. In 5G, [massive MIMO](#) leverages dense arrays with up to a few hundred antenna elements at the base station to serve many users simultaneously, while greatly improving spectral efficiency and overall performance. Looking ahead to 6G, Giga-MIMO pushes this evolution further by incorporating thousands of antennas alongside advanced signal processing techniques. This approach unlocks wideband channels in



**Figure 1. Improving capacity, coverage, and uplink latency with Giga-MIMO and subband full duplex**

the upper-midband spectrum for 6G wide-area coverage, enabling rapid, co-sited deployment of 6G networks that deliver massive gains in throughput and consistent, high-quality user experiences far exceed what was possible in previous generations.

Full duplex communication enables simultaneous transmission and reception over the same channel, improving spectral efficiency. Subband Full Duplex (SBFD) constrains full duplex to distinct downlink and uplink subbands within a single time division duplex (TDD) carrier. While Giga-MIMO solves the capacity challenge, SBFD tackles UL coverage and latency. A typical configuration might allocate a 400 MHz total bandwidth with 100 MHz dedicated to uplink and 300 MHz to downlink. With these foundational elements in place, let us consider the new demands that 6G networks must address.

## Address future use cases and demands

The [next generation of AI user experiences](#) that continually create, analyze and share data will drive the need for higher capacity in the uplink and downlink. Immersive XR, connected vehicles and mobile robots will also rely on wide-area, responsive connectivity for sensor data, control signals and collaborative intelligence. In addition, 6G networks with full-duplex capability will open the door to support [integrated sensing and communication \(ISAC\)](#), enabling the wireless infrastructure to not only connect devices but also sense and interpret the surrounding environment. This capability will power advanced applications such as environmental mapping, object detection and real-time situational awareness for autonomous systems.

By dramatically scaling network capacity and reducing latency, especially for uplink traffic, Giga-MIMO and SBFD enable responsive, reliable connectivity and sensing for emerging use cases.

At the same time, these technologies keep deployment pragmatic and cost-efficient, ensuring that operators can support new applications without prohibitive complexity or expense.

Achieving these capabilities depends on unlocking new spectrum resources and deploying advanced antenna technologies, setting the stage for a truly intelligent and user-centric 6G era.

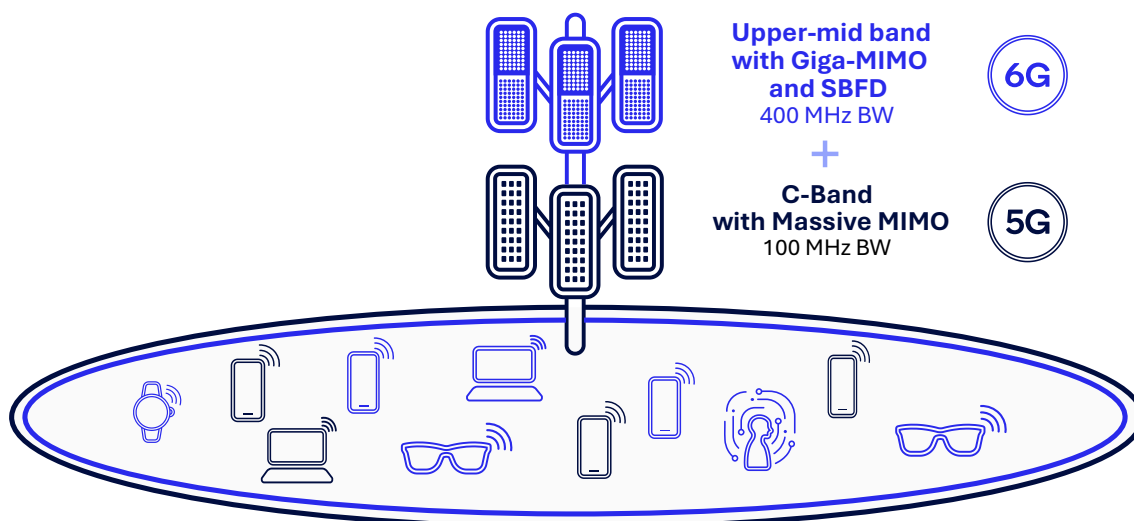


Figure 2. Use Giga-MIMO and SBFD to co-locate upper-mid band 6G with mid band 5G

## Unlock spectrum with technology

High performance mobile connectivity and high-resolution sensing depend on access to wideband spectrum. [Spectrum between 7 and 15 GHz](#), known as Frequency Range 3 (FR3) in the 3GPP ecosystem, offers sizable contiguous bandwidth to meet 6G requirements. Although higher frequencies increase propagation loss, they also have shorter wavelengths that allow more antennas to fit into the same antenna panel form factor used for lower mid-bands. Giga-MIMO in FR3 increases antenna counts significantly without increasing the overall panel size, with prototypes featuring thousands of antenna elements and hundreds of transmit-receive chains.

For the same conducted power, Giga-MIMO arrays improve the effective isotropic radiated power (EIRP) through narrower beams and can compensate for the additional propagation losses of higher frequencies. This enables wide-area coverage comparable to lower-midband coverage, while providing much higher throughput due to better spatial multiplexing.

Full duplex operation is challenged by interference: self-interference at the base station (gNB), cross-link interference (CLI) between gNBs on the same or different sites, and inter-UE cross-link interference can reduce UL/DL SINR and cause measurable losses in throughput and coverage if not properly mitigated.

Multiple solutions have been developed to mitigate the various sources of interference arising from SBFD operation:

- Large spatial isolation using separates transmit and receive panels, augmented by electromagnetic spatial duplexers.
- RF subband filtering boosts receiver selectivity.
- Analog cancellation protects the low-noise amplifier (LNA).
- Digital cancellation models and subtracts nonlinear leakage; digital predistortion (DPD) reduces emissions.
- Beamforming creates spatial nulls to suppress interference.
- Scheduler coordination avoids harmful pairing; beam-pair selection at higher bands further reduces coupling.



Figure 3. Over-the-air performance of subband full duplex in 3.5 GHz

## Set up for successful 6G rollouts

Deployment can be pragmatic: new 6G sites can be co-located with existing 5G base stations, accelerating rollout and leveraging current investments in siting, backhaul and power. Giga-MIMO is well-suited to hybrid beamforming, blending flexible digital processing with efficient analog control to keep complexity and power consumption in check.

When SBF and TDD base stations coexist, even in adjacent channels, one base station's transmitter can interfere with a neighboring base station's uplink reception. SBF base stations avoid CLI with adjacent TDD operators by introducing uplink subbands to downlink time slots. Placing the uplink subband in between two downlink subbands creates frequency isolation that further reduces interference coupling from neighboring TDD cells. When interference does occur, it is measurable and mitigable. Interference measurements identify which gNB pairs are most affected, guiding power back-off, restricted beams and protected resources for low-latency traffic.

Together, these technologies enable business models that depend on responsiveness and scale, with attention to reuse and deployment speed. The effectiveness of these strategies is supported by real-world results.

## Rely on field-proven techniques

[Over-the-air measurements at 3.5 GHz](#) with two commercial devices showed that advanced mitigation restored uplink throughput otherwise lost to self-interference. Urban-macro simulations demonstrated that SBF

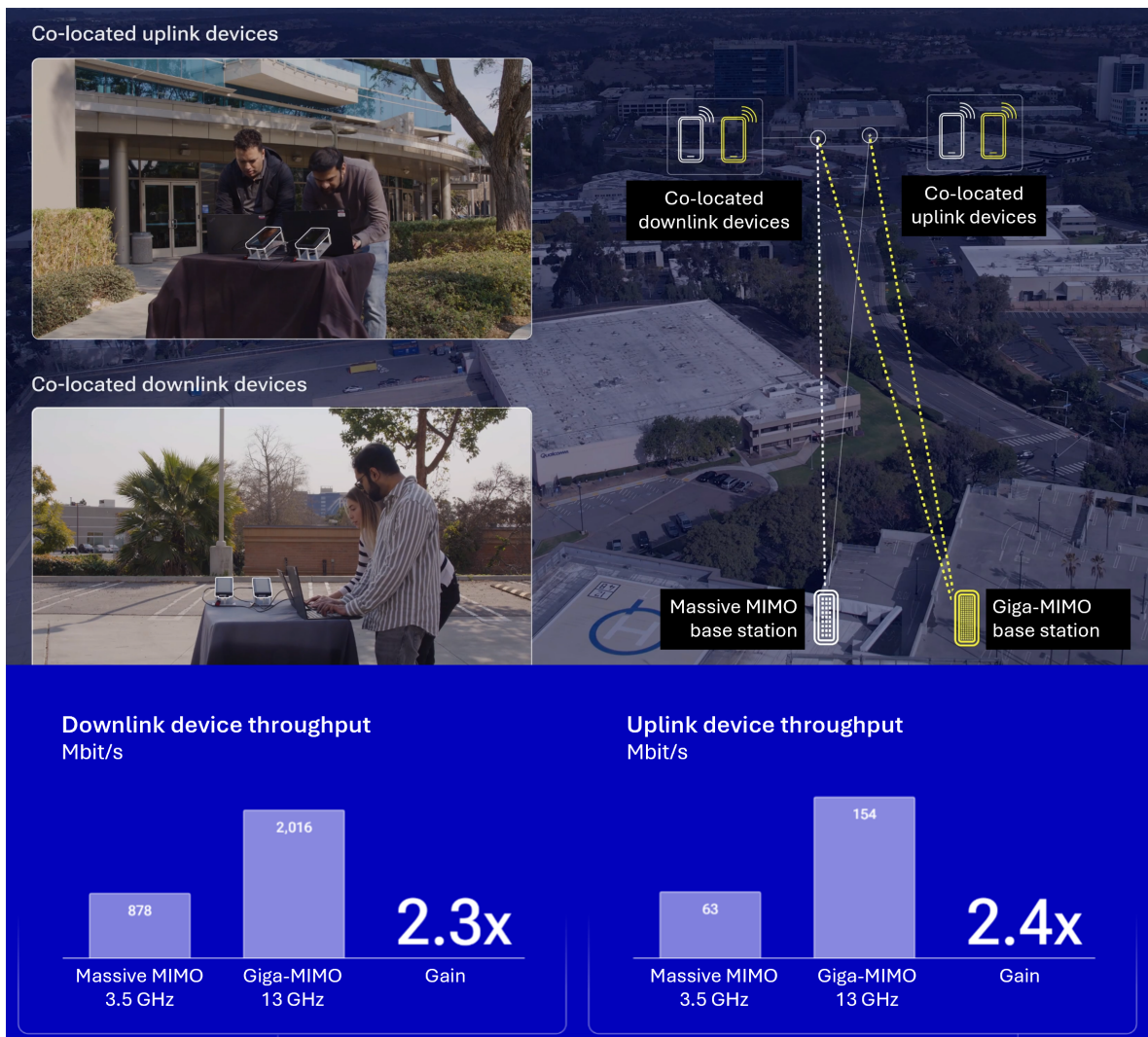


Figure 4. Field-proven 6G performance with Giga-MIMO and SBF



**Figure 5. The hybrid AI architecture spans the device, edge and cloud**

increased the median uplink user-perceived throughput (UPT) by improving uplink duty cycles – scheduling uplink in every slot rather than one in five and reducing median uplink latency by about 50%. With perfect cross-link mitigation, uplink UPT increased by roughly 79% against a baseline TDD configuration; even without perfect mitigation, SBF D outperformed TDD on average, with gains near 44% in uplink UPT. Coverage improved as well, with SBF D serving a higher fraction of users at or above a 1 Mbps uplink target and ~6 dB better maximum coupling loss at the coverage edge with perfect mitigation. These technical advances translate directly into better user experiences, as confirmed by our over-the-air measurements (see Figure 3).

Figure 4 illustrates results from an additional over-the-air test featuring Giga-MIMO and SBF D conducted at our San Diego campus. In this setup, we compared cell-edge performance between two configurations: a 3.5 GHz massive MIMO base station with 100 MHz bandwidth and a 13 GHz Giga-MIMO base station with the same total conducted power offering 400 MHz channel bandwidth. The latter was divided using SBF D into 300 MHz for downlink and 100 MHz for uplink. Our tests with Giga-MIMO and SBF D at 13 GHz showed gains in downlink and uplink device throughput of 2.3x to 2.4x when compared to 3.5 GHz with massive MIMO and TDD.

## Deliver new, responsive experiences

With Giga-MIMO and SBF D technologies, users will benefit from the higher capacity of FR3 spectrum and the better uplink coverage.

Improved responsiveness will power emerging applications: low-latency uplinks will complement hybrid AI architectures, enabling agentic tasks to move efficiently across device, edge and cloud.

Augmented reality will feel smoother, vehicles will exchange sensor data and control messages consistently, and ISAC will allow networks to analyze environmental reflections while maintaining active data streams. SBF D enables this dual capability by transmitting and receiving simultaneously. For these innovations to scale, alignment in standards and policy is crucial. Align standards and policy to scale

Policy and standards determine how quickly innovations become widely usable. 3GPP standards already include mechanisms for managing user-level coexistence in dense scenarios. SBF D has moved through



Figure 6. The 3GPP timeline for 6G standardization

[study in 3GPP Release 18](#), with feasibility and benefits in TDD bands recognized. [Release 19](#) culminated in specifications for SBF D operation at the base station for 5G Advanced, laying groundwork for full duplex evolution in 6G, starting with study items in Release 20. Importantly, SBF D operates within existing TDD regulatory frameworks. It doesn't require new interference protection rules or guard bands.

Regulatory bodies should continue supporting spectrum frameworks that allow upper midband access with flexible duplexing in TDD bands, expanding usable bandwidth and making SBF D deployment feasible alongside legacy devices.

As networks grow, the AI-native architecture of 6G will be key to maintaining performance sustainably.

## Leverage machine learning to improve Giga-MIMO performance

[Machine learning-based channel state feedback \(CSF\)](#) enables the accurate channel information needed for the narrow, high-precision beams in Giga-MIMO systems. By adapting CSF to each device's channel conditions, machine learning improves the fidelity of channel reconstruction while keeping feedback overhead low. This more accurate and efficient channel state information (CSI) empowers the base station to form tighter beams, support denser multi-user operation, and boost throughput and spectral efficiency as antenna arrays scale to Giga-MIMO dimensions.

In multi-vendor scenarios, [ML can be trained sequentially across vendors and nodes](#), matching joint training performance while easing integration. Real-time over-the-air ML tunes parameters and resource allocation as conditions change, a necessity when beams are narrow and user distributions shift quickly.

## Building the 6G Ecosystem Together

The future of 6G depends on collaboration. By bringing together expertise across leadership, policy, research, product, engineering and operations, upper midband spectrum can be launched successfully. These networks will be designed for massive capacity, low latency and intelligent adaptability, powered by Giga-MIMO and SBF D—well-understood, field-validated techniques in mobile network evolution, delivering advantages in coverage, capacity, coexistence and latency. By working together to realize this vision, 6G networks will enable immersive experiences, autonomous systems and AI-driven services for the next decade and beyond.



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