Multibeam vs mMIMO

Introduction

As global data demand continues to surge, cellular systems must deliver higher capacity, lower latency, and greater spectral efficiency. Conventional single-beam macro or small-cell antenna systems can result in cell-sector saturation and insufficient to handle high user density, interference, and limited spectrum availability. These factors lead to slower data rates, dropped calls, and connection failures. This problem becomes especially evident during large public events such as concerts, sporting events, and festivals, or busy city centers or landmarks where thousands of users simultaneously stream video or access high-bandwidth applications, pushing network capacity to its limits and degrading overall performance.

To address these challenges, vendors have introduced advanced antenna technologies aimed at enhancing network efficiency, including:

- Multibeam antennas
- Massive Multiple-Input Multiple-Output (mMIMO) antennas

Both multibeam and mMIMO technologies significantly enhance link quality by improving the signal-to-interference-and-noise ratio (SINR). These improvements translate into broader network coverage, increased capacity, and higher user throughput compared to legacy single-beam antennas. This whitepaper presents a detailed comparison of multibeam antenna systems and mMIMO.

mMIMO vs Multibeam Antennas

A mMIMO antenna integrates dozens or even hundreds of radiating elements, allowing the base station to serve many users simultaneously within the same time-frequency resources. It relies on real-time digital beamforming, spatial multiplexing, and advanced signal processing to dynamically adapt beams toward active users.

mMIMO adds spatial dimension to existing time and frequency resources. Its digital beamforming enables flexible control of azimuth and elevation, efficient null forming, and adaptive user multiplexing. However, its benefits diminish when constrained by limited aperture size and FDD band limitations. mMIMO introduces several architectural and operational challenges:

- High system complexity due to dynamic beam steering and real-time signal processing. Increased size, weight, and power consumption from multiple front-end modules (FEMs) and RF chains.
- Additional control electronics and calibration requirements for adaptive interference mitigation.

- Performance degradation in FDD bands, as mMIMO operates most effectively in TDD systems where uplink and downlink share the same frequency.

Conversely, multibeam antennas address these challenges through simpler, more efficient architectures:

- Multiple spatially separated beams are generated from a single aperture, each targeting a different region or user.

A single multibeam antenna can support multiple services and frequency bands, reducing site complexity and energy consumption. Deployment is easier because a single compact antenna replaces multiple sectorized panels.

FDD Band Limitations of mMIMO

- **Channel State Information (CSI) Challenge:**
  mMIMO relies on accurate CSI for beamforming. In FDD systems, the uplink and downlink operate on different frequencies, meaning CSI estimated on the uplink is not valid for downlink transmission. This frequency separation limits beamforming gain in FDD bands.

- **Intermodulation Distortion (IMD):**
  Active antennas in mMIMO introduce both passive and active intermodulation distortion. Each sub-array or element group requires duplexers to separate transmit and receive paths, increasing hardware complexity and risk of IMD. In integrated active arrays, diagnosing and mitigating IMD becomes extremely difficult.

These issues make mMIMO less spectrum-efficient in FDD networks. As most global operators maintain significant FDD holdings, multibeam antennas offer a more practical, spectrum-efficient solution that supports both FDD and TDD bands within a single compact design.

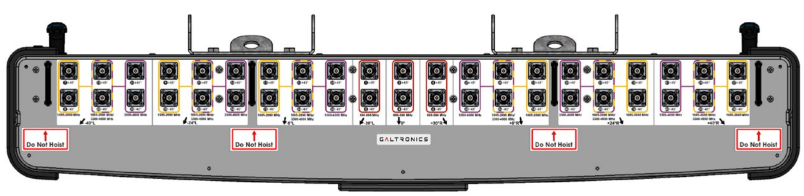
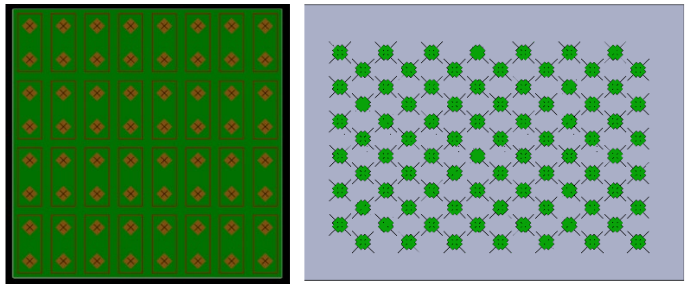


Figure 1: A Galtronics multibeam antenna that provides full coverage across all FDD and TDD bands within the 698–4000 MHz range.

Aperture and Beamwidth Constraints

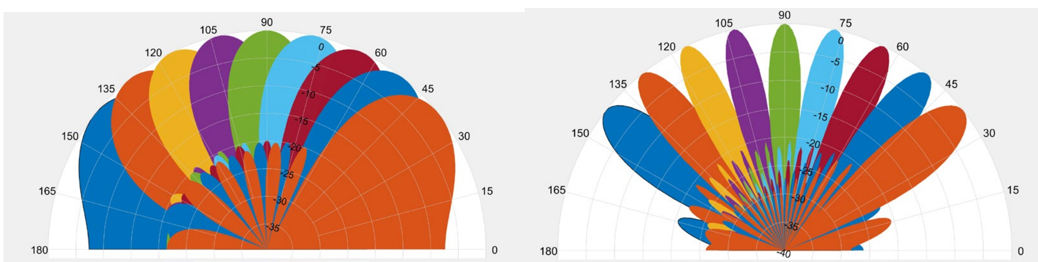
Typical 32T32R or 64T64R mMIMO arrays have only eight azimuth columns due to one RF chain per one-to-three antenna elements. Enlarging the array increases hardware cost and digital processing load, limiting practical array growth. This results in wide azimuth beams and increased beam overlap, leading to inter-beam interference and reduced per-user SINR in dense deployments.

In contrast, multibeam antennas can scale azimuth aperture independently since each beam requires only one radio path rather than one per element. This enables narrower beams, higher order sectorization, and reduced interference between adjacent beams. Although mMIMO can digitally generate many overlapping beams, this comes at the expense of increased interference and reduced frequency reuse.



64T64R Array Passive Multibeam Array

Figure 2: A 64T64R active array compared to its passive multibeam counterpart with an arbitrary number of radiating elements.



9-beam using MMIMO 9-beam using a passive multibeam

Figure 3: Beamformer generating 9 beams using mMIMO array and its counterpart passive multibeam array.

Field results and operator trials consistently show that mMIMO throughput initially scales with the number of users but declines linearly in dense user environments due to interference coupling. Passive multibeam systems, by contrast, maintain more stable throughput because of their fixed, spatially orthogonal beam patterns.

Table 1: System-level comparison between mMIMO and multibeam technologies.

Feature	**mMIMO**	**Multibeam**
Beamforming Type	Digital (dynamic)	Passive / Hybrid (fixed or switchable)
Suitability	TDD-optimized	TDD & FDD compatible
Complexity	High (per-element RF chains)	Low (shared feed network)
Power & Weight	High	Moderate / Low
Azimuth Beamwidth	Wide (8-column array)	Narrow (high order sectorization)
IMD & Calibration	Complex	Simple
Sustainability	Energy-intensive	Lower power footprint

Multibeam for Venues

High-density venues such as stadiums, arenas, and convention centers demand extreme capacity, tight interference control, and predictable performance during short but intense traffic peaks. To set up an upper-bound reference point for what a conventional Sub-6 GHz macro sector can deliver today, we estimated the largest theoretical throughput achievable when fully using all available low-band (LB), mid-band (MB), and C-band (CB) spectrum with best-case commercial radio configurations. The analysis includes legacy 2T2R/4T4R radios and modern 64T64R mMIMO units running with high-order modulation (1024-QAM) and full MIMO layer support.

In this model, the LB spectrum (617–960 MHz) contributes approximately 50 MHz of aggregated FDD bandwidth using 2T2R/4T4R radios. The MB range (1695–2690 MHz) adds roughly 80 MHz of additional FDD capacity across AWS, PCS, DCS, and 2100/2600 MHz The CB range (3300–4200 MHz) provides a contiguous 100 MHz TDD carrier using a 64T64R mMIMO array capable of up to 16 spatial layers under ideal propagation conditions.

Together, these bands yield a combined theoretical sector-level throughput of ~16 Gbps-representing the practical upper limit of what current legacy and mMIMO Sub-6 GHz assets can deliver at peak spectral efficiency. While not a deployable real-world configuration, this benchmark is a useful reference for comparing traditional sectorized architectures against next-generation spatially efficient antenna solutions.

Table 2: Maximum Theoretical Throughput for a Single 120° Sub-6 GHz Sector.

Band	Frequency Range	Bandwidth Used	Radio Type	MIMO Layers	Modulation	Throughput (Gbps)
LB	617–960 MHz	50 MHz (FDD)	2T2R / 4T4R	4 layers	1024-QAM	1.8
MB	1695–2690 MHz	80 MHz (FDD)	4T4R	4 layers	1024-QAM	2.9
CB	3300–4200 MHz	100 MHz (TDD)	64T64R mMIMO	16 layers	1024-QAM	11.5
Total	—	**230 MHz (agg.)**	Mixed	—	—	**≈ 16.2**

Venue Capacity Requirements Exceed Macro-Sector Limits

In modern stadiums and arenas, tens of thousands of spectators simultaneously upload and stream video, use social media, order concessions, and access real-time stats. For instance, a German Bundesliga private 5G deployment is dimensioned for ~500 Gbps of in-stadium traffic for an audience of ~43,000 people-highlighting that busy-hour capacity targets for top-tier venues routinely exceed 100 Gbps.

From a radio-access perspective, this makes it clear that a single macro sector-even with a theoretical peak of ~16 Gbps across all Sub-6 GHz assets-cannot meet full-venue capacity requirements. Instead, capacity must be expanded through spatial distribution across multiple bands, layers, sectors, and beams, or through new antenna architectures that significantly increase spatial reuse.

Why Multibeam Antennas Excel in Venues

Multibeam base-station antennas address this challenge by dividing a conventional 90°–120° sector into multiple narrow, high-gain, interference-isolated beams. Each beam can be individually connected to a radio or DAS node, allowing targeted coverage of specific seating blocks or concourse areas. This approach enables:

- Aggressive spatial frequency reuse
- Higher SINR and reduced interference
- More predictable user throughput
- Superior performance across the FDD spectrum where mMIMO is less effective.

Unlike fully digital mMIMO systems, multibeam antennas provide deterministic, frequency-stable beam patterns across low- and mid-band FDD spectrum, making them highly attractive for multi-operator and multiband venue deployments.

All major U.S. and Canadian carriers deploy Galtronics multibeam antennas, extensively used in Mexico in preparation for the World Cup, and widely adopted across Europe due to their combination of performance, weight, and cost efficiency.

Carrier Field Evidence: Multibeam vs. 64T64R mMIMO

Multiple Tier-1 carriers have recently conducted live-event evaluations-including Formula 1 races, and large music festivals in North America and Europe to compare Galtronics Multibeam performance against 64T64R mMIMO systems. These results (Table 4) clearly demonstrate that in crowded venues where user distribution is uneven, and channel conditions vary rapidly, clean, spatially isolated multibeam architectures consistently outperform digital mMIMO beamforming. Multibeam systems deliver superior aggregate capacity, more stable per-user throughput, and better spectral efficiency, making them the preferred solution for demanding stadium and arena environments.

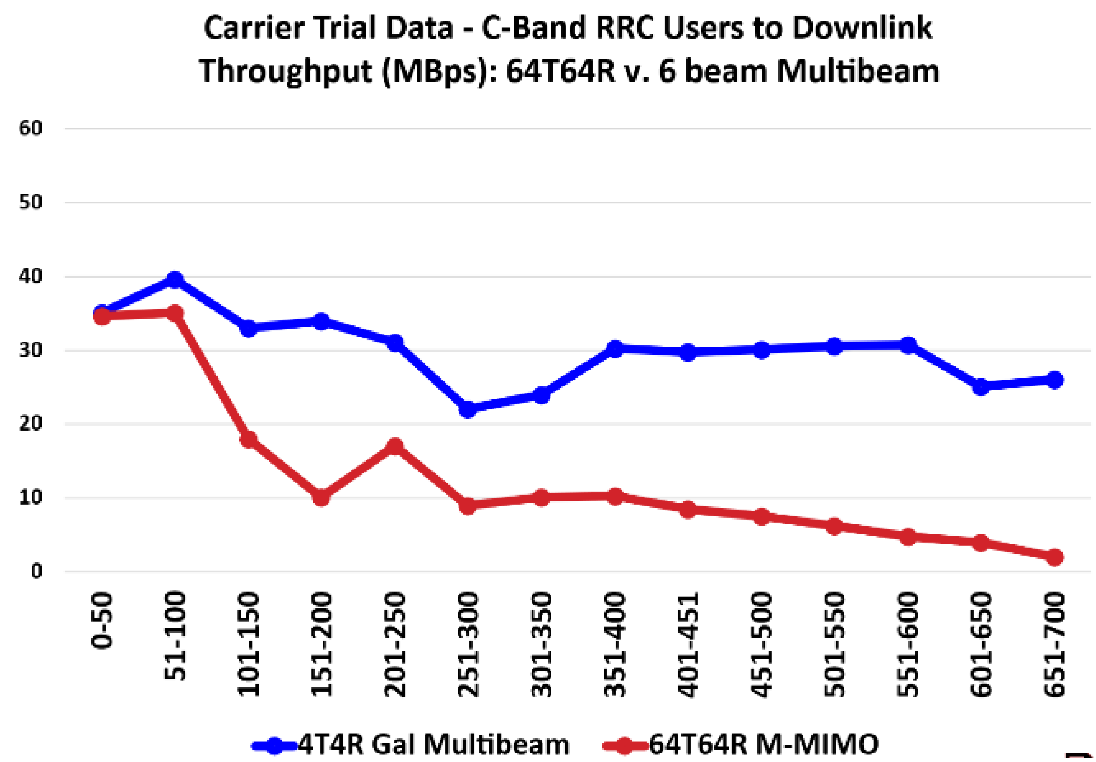


Figure 4: North American Tier I Carrier Field Evidence: Galtronics Multibeam vs. 64T64R MMIMO.

Table 3: North American Operator Field Trial: Galtronics Multibeam vs. 64T64R MMIMO.

Category	64T64R mMIMO (C-band)	Galtronics Multibeam (6-beam, C-band + 4T4R radios)
Test Configuration	64T64R digital mMIMO radio	6-beam passive Multibeam antenna + 4T4R radios
Throughput Under Load	Throughput collapsed as user count increased; rapid saturation	Throughput remained stable even at high user counts
Per-User DL Throughput	<10 Mbps once RRC users >100; only a few Mbps at heavy load	Stable **25–35 Mbps** per user up to ~700 users
Total Sector Capacity	Baseline	**2.6× higher** than mMIMO
Downlink Throughput	Baseline	**3.2× higher** than mMIMO
Uplink Throughput	Baseline	**24% higher**, due to cleaner beams and improved SINR

Another trial was conducted at the Glücksgefühle Music Festival in September 2025, with 250,000 people attending. Galtronics dual band 4G/5G (TDD+FDD) multibeam was tested against mMIMO and legacy FDD antennas. Multibeam offered superior RF performance in both FDD and TDD bands over the legacy (4G) and TDD mMIMO (5G) antennas.

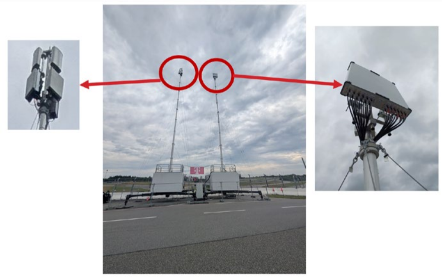


Figure 5: Galtronics multibeam trial against mMIMO and legacy panel antennas at Glücksgefühle Music Festival in Germany.