SOLUTION BRIEF

Spirent Massive MIMO Test Solution | Sub 6GHz

Simplifying 5G Conductive RF Testing

Massive multiple input multiple output (MIMO) is a key physical layer technology for 5G applications, which involves the use of large-scale antenna arrays that contain as many as 256 elements. Implementing 3D beamforming along with massive MIMO technology improves the capacity limitation of an entire 5G system by adding data streams, increasing the signal to noise ratio, and reducing interference.

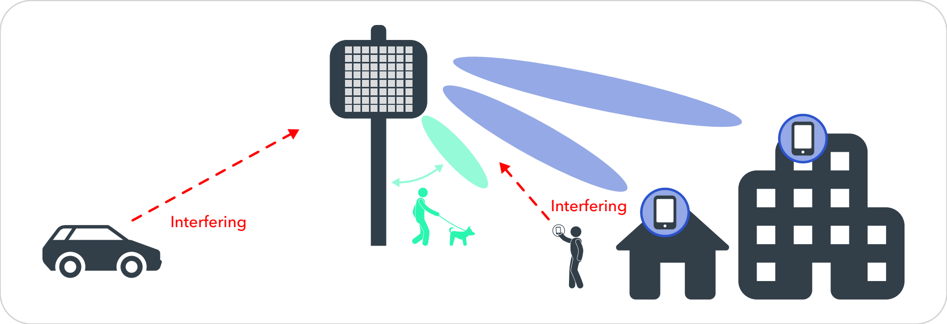
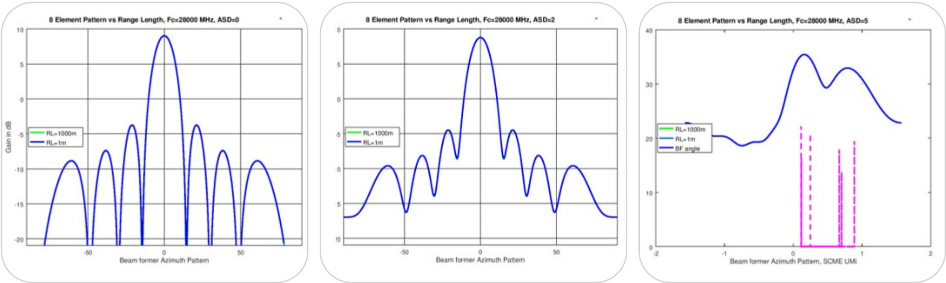


Figure 1. Typical view of massive MIMO beamforming in a live network

In an ideal open space environment, the massive MIMO antenna array can create well-shaped high-gain beams for target devices, but in a real cellular network, propagation conditions are very complicated - the signal or beam may be reflected or scattered through different objects; the plane wave can form into multiple signal clusters (paths) with different delays, orientation of arrival and angle spread; and the beam shape can also change due to the propagation environment. Figure 2 shows examples of beamforming under different propagation conditions.



Clean channel | Single path with angle spread | With multipath impact

Figure 2. Examples of beamforming under different propagation conditions

Due to the complexity of propagation environments in massive MIMO scenarios, channel emulation is a critical aspect of testing the performance of 5G base stations (gNBs) and user terminals (UTs).

Conductive testing is an important lab test methodology for frequencies below 6GHz. Based on the development stage of the gNB or UT, different test solutions can be used for beamforming performance evaluation.

Performance Testing of:

- Massive MIMO with mobile terminals
- 3D beamforming with 5G gNBs
- Mobility scenarios in 5G systems

Three solutions to choose from... three paths forward

1. Functional testing of beamforming

For basic beam tracking or beam sweeping features, performance can be tested with a phase matrix instrument. Phase matrix instruments have massive MIMO radio links (such as 64x8, 64x16) inside the instrument, and can independently change the phase and attenuation of each radio link. By updating the phase and loss table of the phase matrix instrument, it can simulate the direction and width in the change of beam lobes.

With this phase matrix test system (Figure 3), you can functionally test beamforming features in Line of Sight (LOS) signal environments. Basic beamforming algorithms can be verified with this low cost and easy-to-setup test solution.

2. Advanced beamforming test solution

To simulate complicated geometrical channel condition impacts to beamforming, Spirent has developed an innovative massive MIMO test solution that provides an economic and practical way to test the performance of massive MIMO and 3D beamforming systems in a lab environment. The solution, shown in Figure 4, integrates Spirent's industry-leading Vertex® channel emulator with a phase matrix instrument to provide a low cost, easy-to-use integrated system that can verify the performance of massive MIMO gNBs or UTs.

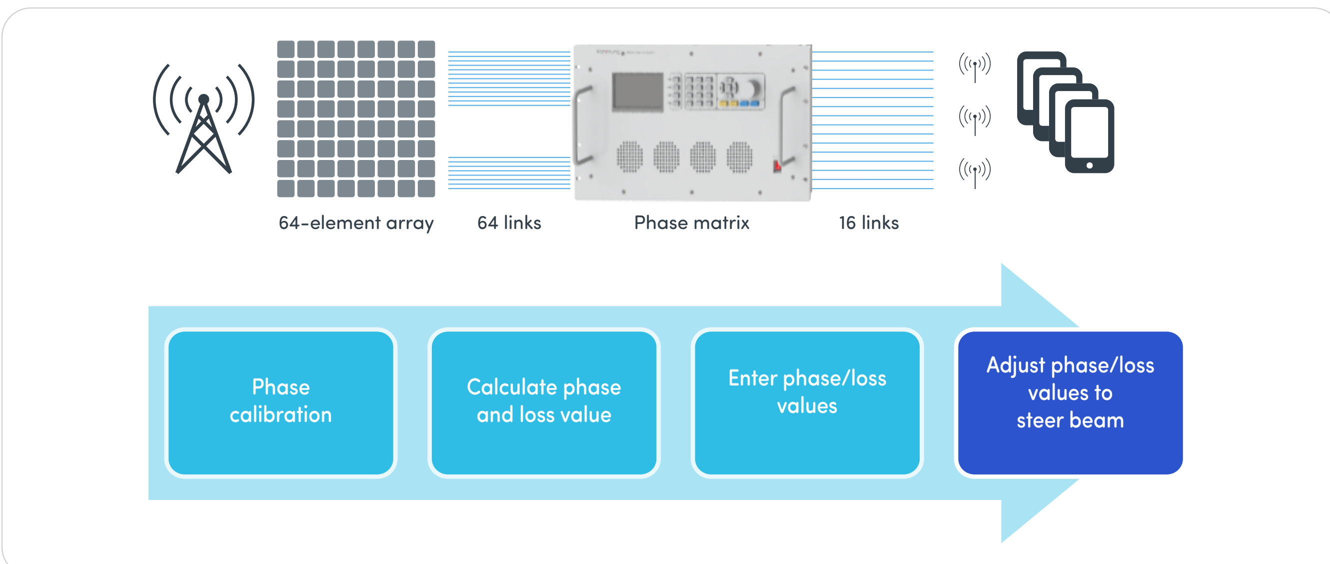


Figure 3. Functional beamforming test with phase matrix instrument

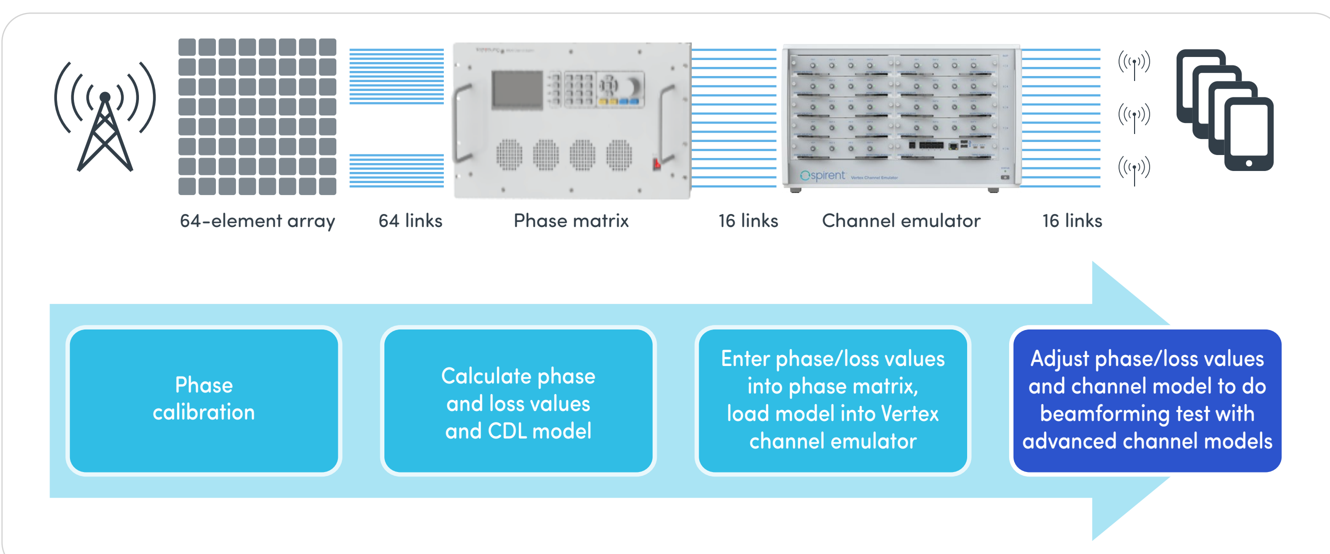


Figure 4. Advanced beamforming test with phase matrix and Vertex channel emulator

The Vertex + phase matrix solution can be used to test up to 64x16 single-user or multi-user system scenarios. Optimized 3D geometric channel models (GCMs) are used to create 3D beamforming and channel emulation scenarios as in the real network. It can also be used to simulate dynamic scenarios such as one device or multiple devices in motion.

But, as the phase matrix has about 50dB native insertion loss, it limits dynamic range power simulation. Also, the phase matrix usually cannot support a frequency range as wide as the Vertex channel emulator. For beamforming tests with multiple bands, you may need multiple models of the phase matrix.

With the Vertex + phase matrix test system, you can verify basic beamforming functionality as well as the capability of 5G base stations and mobile devices to deal with complicated beamforming environments, since the signal beams are shaped by angle spread and multi-path fading. This system can support basic 3D geometrical channel models defined in 3GPP 38.901 specifications.

3. The most comprehensive beamforming test solution

Comprehensive beamforming tests can be performed with a massive MIMO channel emulation solution consisting of multiple Vertex channel emulators, as shown in Figure 5. Up to 8 Vertex instruments can be integrated together as a single system with the Spirent Vertex Baseband Synchronizer at digital band. A four-Vertex system can perform 64x4 and 64x8 bidirectional beamforming tests.

The system can support all kinds of cluster delay line (CDL) models, it can cover all frequency bands of sub 6GHz (from 30MHz to 6GHz) and provide more than 100dB dynamic power range.

This is the most complete wireless channel emulation solution for massive MIMO performance testing. This system can cover the whole range of sub-6GHz frequency bands, simulate all kinds of 3D geometrical channel models, and can simulate environments with a large dynamic range for device motion.

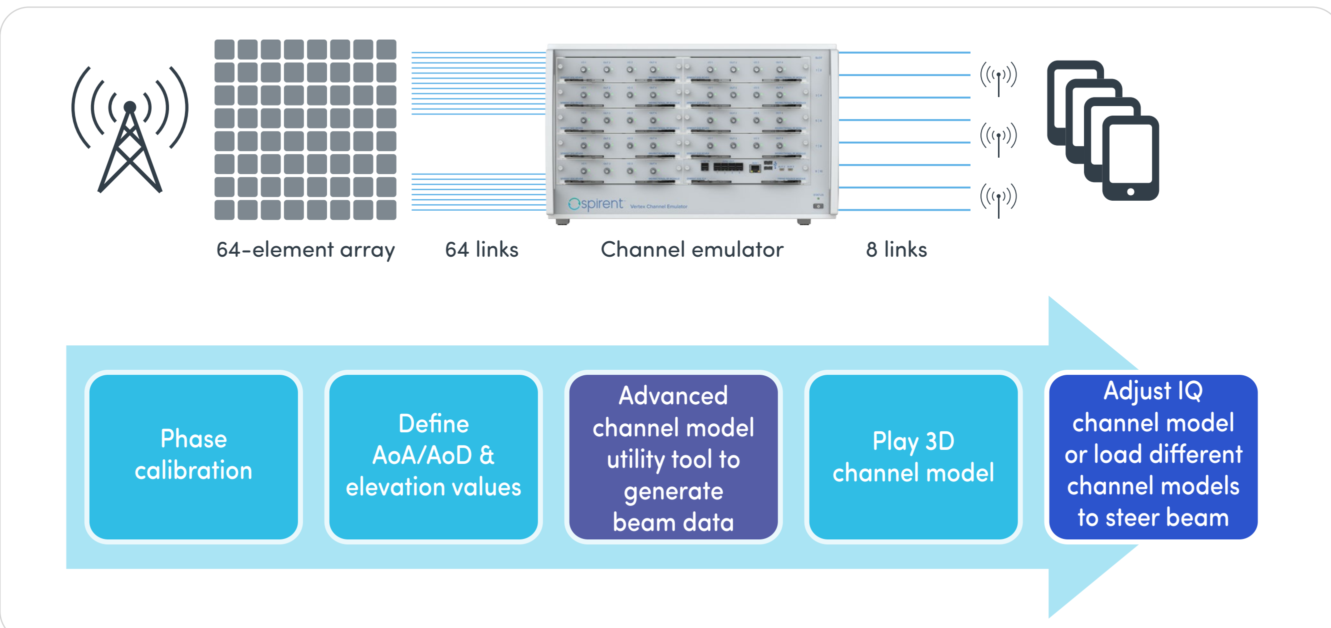


Figure 5. Complete beamforming test solution with multiple Vertex channel emulators

Comparison between the different types of beamforming test solutions

There are key differences between the three solutions just discussed and it is critical to ensure the chosen solution will target the key performance indicators required for the specific application needs. See table for a brief comparison.

Capability	Phase matrix only	Phase matrix + Vertex	Multi-Vertex system
Channel conditions	Static line of sight signal	3D GCM channel model	3D GCM channel model
Power Dynamic range	About 60dB	About 40dB	>100dB
Frequency coverage	About 2G of each model	Based on the range of phase matrix	Full range from 30MHz to 6GHz
Loading model	One step to phase matrix	Two steps: phase matrix, Vertex	One step to Vertex
Beamforming method	Change phase and loss of radio link	Change phase, loss of radio link or AoD of model	Change phase, loss of radio link or AoD of model
3D motion simulation	Static link motion	Motion with channel model, need to synchronize between phase matrix and Vertex	Full 3D motion with channel model simulated in Vertex
Model Generation	Phase calculation tool or ACM software	ACM software	ACM software or real-time fading engine

Solution components

Spirent Vertex Channel Emulator

The Vertex channel emulator is an advanced platform that replicates the comprehensive noise and spatial conditions of even the most complex wireless channels. Its cutting-edge capabilities enable users to emulate a real-world radio frequency (RF) environment in the lab, making it possible to isolate and identify performance issues early in the development cycle.

Incorporating a modular RF front end with a powerful signal processing core, Vertex achieves an unprecedented level of scalability and flexibility, enabling it to efficiently address a broad range of applications from low channel density such as 2x2 MIMO to high channel density such as MIMO beamforming, MIMO OTA, carrier aggregation, massive MIMO and antenna array systems (AAS). Vertex can support frequencies from 30MHz to 6GHz within a single hardware platform. Each RF channel can support up to 200MHz bandwidth and concatenate for widths up to 1GHz.

Figure 6. Vertex channel emulator

Spirent Advanced Channel Modeling Software

Advanced Channel Modeling (ACM) is a PC-based software application designed to create a framework that acts as a common platform to enable the integration of various channel modeling algorithms. It has a graphical user interface (GUI) to edit base station configurations, mobile station configurations, and 3D GCM parameters.

This powerful software tool can generate both IQ playback-based 3D channel models and real-time based channel models, in static and mobility scenarios.

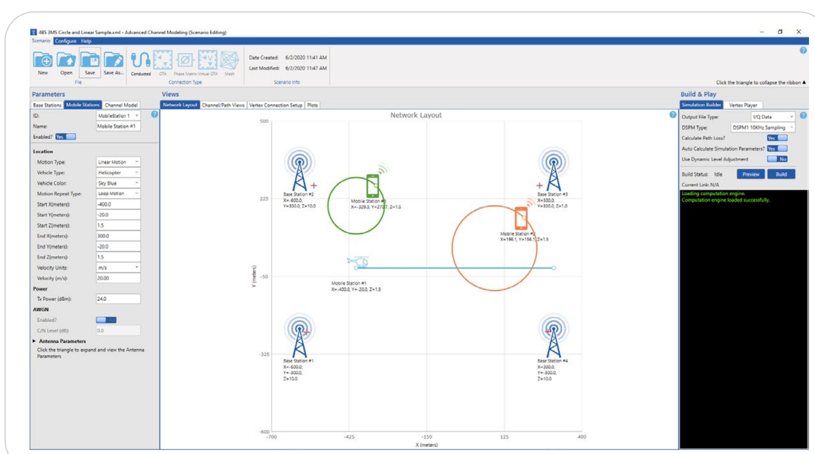


Figure 7. Spirent Advanced Channel Modeling software

Topyoung MCS phase matrix

The MCS phase matrix is used for beamforming and beam tracking due to its ability to quickly change the phase and amplitude of each MIMO link.

It can support 64x16 or 64x32 MIMO links with phase and amplitude control in independent channels and can create 3D clusters with any RF channel combination of attenuation and phase changes for 3D beamforming tests.

All RF channels can complete attenuation and phase responses within 1ms. This provides beam tracking function verification to test the response speed of the gNBs.

Figure 8. Topyoung phase matrix instrument

A glossary of beams

Beamforming: a technique that focuses a wireless signal towards a specific receiving device, rather than having the signal spread in all directions from a broadcast antenna, as it normally would. The resulting more direct connection is faster and more reliable than it would be without beamforming.

Beam lobe: a curved or rounded projection as part of an antenna pattern. The main lobe is the lobe containing the higher power. The beams with lesser power are called side lobes.

Beam steering: refers to changing the direction of the main lobe of a radiation pattern. It may be accomplished by switching the antenna elements or by changing the relative phases of the RF signals driving the elements.

Beam sweeping: a technique to transmit the beams in all predefined directions in a burst in a regular interval.

Beam switching: a method of more accurately obtaining the bearing or elevation of an object by comparing the signals received when the beam is in slightly differing directions in bearing or elevation. When these signals are equal, the object lies midway between the beam axes.

Beam tracking: the methodology to follow a beam on a particular propagation path defined by a pair of angles of arrival (AoA) and angles of departure (AoD).

Did you know

Massive MIMO beamforming with large-scale gNB and UT antenna arrays results in extremely complicated and intricate environments that can be difficult to model in a lab setting for testing purposes. With three high-performance solutions available, Spirent experts can help you understand which one is right for your application needs.

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