# Massive MIMO:

# 8 THINGS TO CONSIDER

The purpose of this e-book is to provide a concise overview of key aspects of massive MIMO technology and test. Further information, and more detailed explanations, can be found in several application notes and technical information at **www.rohde-schwarz.com**

**Note:** Please find more information at **www.mobilewirelesstesting.com**

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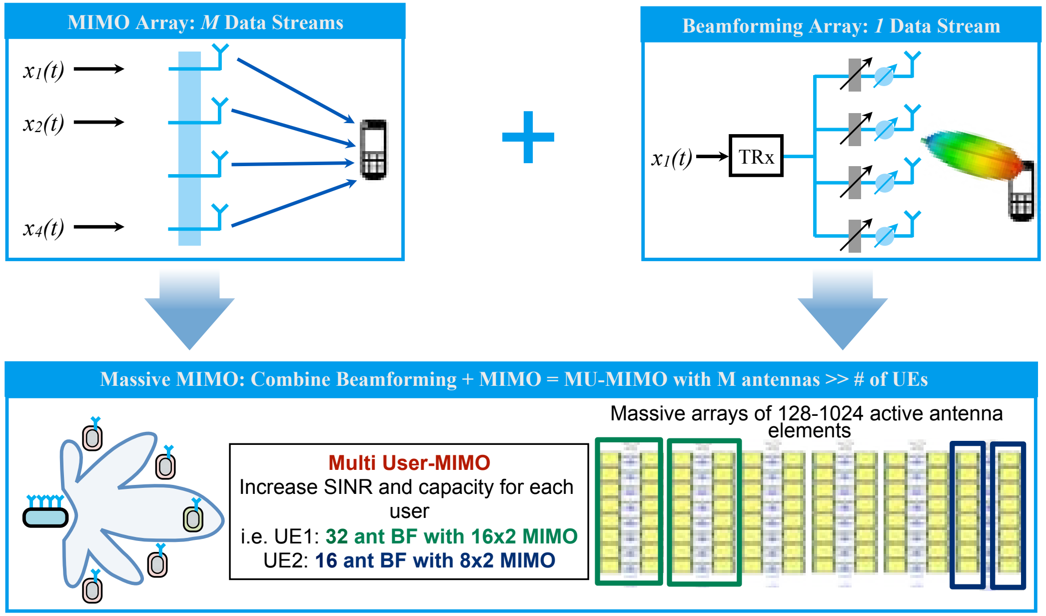
1

# What is Massive MIMO?

Multiple Input Multiple Output (MIMO) is a technology that has been in use for many years that utilizes many antennas at the transmitter and the receiver to improve diversity gain, take advantage of uncorrelated propagation paths for higher efficiency and high throughput and/or for multiple access for different users simultaneously.

In massive MIMO systems, a very high number of antenna elements is used at the transmitter and receiver, which now allows for two major concepts to be dynamically combined; beam forming and spatial multiplexing – both brought about by the ability of the many antenna elements to focus their energy into smaller regions of space. If an antenna system can do this, we refer to that antenna system as massive MIMO.

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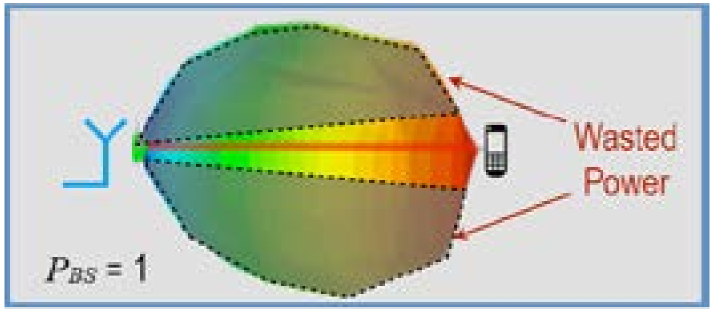
# 2 Why use Massive MIMO?

There are many advantages in using massive MIMO with beamforming. The most important one is the improvement in energy efficiency brought about by increasing the antenna gain by bundling the transmitted energy. Doing this also brings about an increase in range and a reduction in inter-cell interference. At higher frequencies (e.g., millimeter wave) there is the additional challenge of higher path loss, but the advantage of smaller antenna size. At higher frequencies, the large number of antenna elements can be used to generate a very narrow beam with large gain, and at lower frequencies, the large number of antenna elements can be used to generate multiple spatial streams.




Using beamforming strategies in terminals and base station equipment will require the need for over-the-air testing to ensure that the beams are pointing in the right direction, as opposed to standard conducted testing. At high frequencies, conducted testing becomes much more challenging and expensive because of the high losses associated with the cables.

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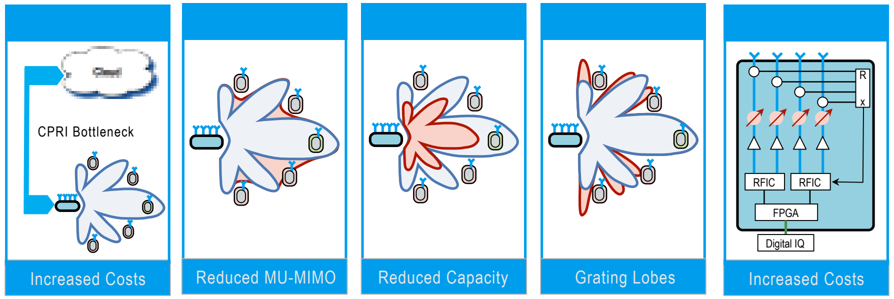
## What are the biggest challenges with Massive MIMO?

Although many advantages, massive MIMO has many challenges to consider:




**Data bottleneck.** There is the potential to create a data bottleneck due to the large amount of data being sent and received by the massive MIMO antenna systems as part of a centralized RAN system, requiring adequate fiber bandwidth.

**Calibration:** Given the large number of antenna elements, beamforming antennas that are not calibrated properly will suffer from unwanted emissions in unwanted directions; e.g., beam squint, which is basically jitter of the beam boresight.

**Mutual coupling:** Mutual coupling between antenna elements results in energy loss and thus a reduction in the maximum range.

**Irregular arrays:** In going from theory into practice, some antenna arrays will need to be designed in non-geometric shapes that may result in dissipating energy in undesired directions.

**Complexity:** Massive MIMO antenna systems represent a new level of complexity from a design, manufacturing, calibration and deployment perspective. And with this new level of complexity also comes the need for new design and test approaches.

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Key Challenges with Massive MIMO

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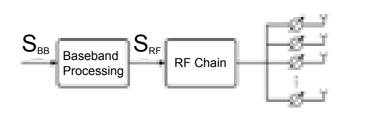
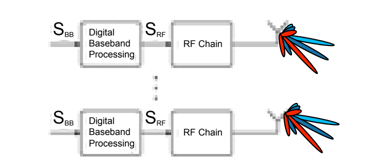
# What are the different types of beamforming used for Massive MIMO systems?

We can achieve beamforming by using an antenna array where the RF signal at each antenna elelment is amplitude and phase weighted. There are 3 possible ways to apply amplitude and phase shifts:



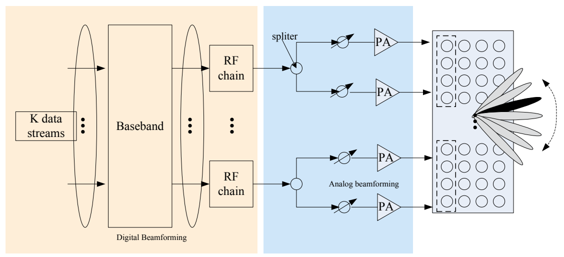

Analog beamforming

**Analog beamforming** – is the traditional appraoch that uses a minimum amount of hardware, making it the most cost-effective method to build a beamforming array.




Digital beamforming

**Digital beamforming** – is an architecture in which each antenna has its own transceiver and data converters, allowing it to handle multiple data streams and generate multiple beams simultaneously from one array. Digital beamforming requires A/D converters making it challenging at higher frequencies.




Hybrid beamforming

**Hybrid beamforming** – these designs are developed by combining multiple array elements into subarray modules. System designers use hybrid beamforming to balance flexibility and cost tradeoffs while still meeting the required performance parameters.

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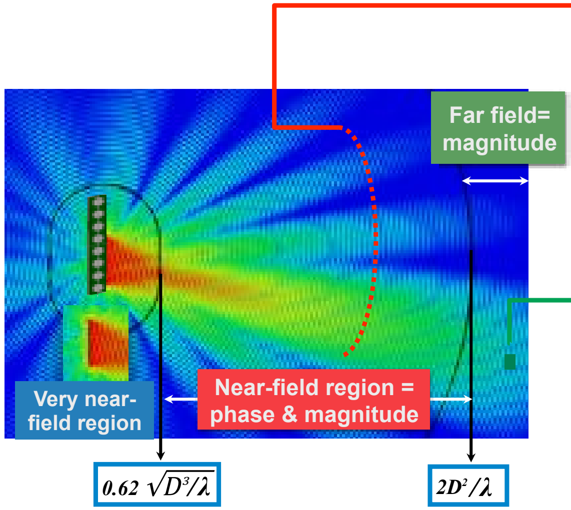
# Are we in the near field or far field? Finding the Fraunhofer distance.

When discussing over the air transmissions, we need to distinguish between various areas. First there is the very near field, or reactive field. This is the result of electromagnetic coupling, with a typical range of only a few centimeters (and not part of the OTA discussion). Secondly, we have the near field, where the obtained measurements depend on amplitude and phase, so you must measure multiple samples on a specific trajectory and then apply some post-processing to convert the data to the far-field; i.e., near-field to far-field transformation. The Fraunhofer distance is the border between the near field and far field and is calculated as $\frac{2 * D^2}{\lambda}$ where D is the aperture size of the antenna array and λ is the wavelength.

Rohde & Schwarz has proposed two additional methods for near-field and far-field estimation; one based on propagation aspects, presenting a kind of "trial and error approach" that uses power measurement variations when changing the measurement distance and another approach based on the half-power beamwidth that reduces the aperture size D into the size of the "radiating part" D* that is typically smaller.




**Near field measurements:**
- Smaller chamber sizes
- Values depend on phase & magnitude - difficult for modulated signals
- Requires NF to FF transformation
- Multiple samples are needed - additional time & effort
- Single antenna probe approach - requires accurate positioner
- Multi-antenna probe approach - calibration is complex

**Far field measurements:**
- Larger chamber sizes - or compact range, which is more complex
- Values depend on magnitude only - good for modulated signals
- One sample is sufficient - no NF to FF post-processing

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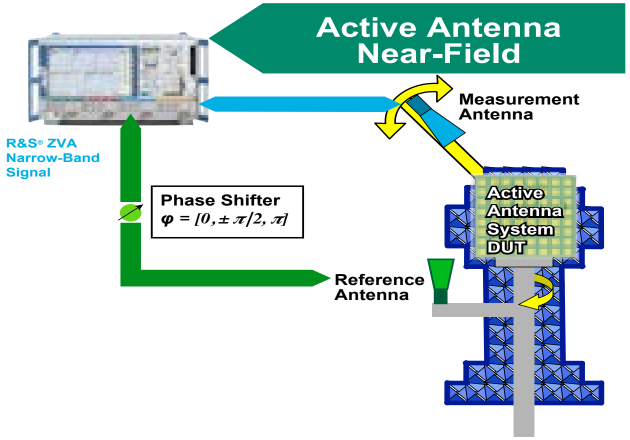
## Is the antenna array active or passive?

Passive antennas utilize the traditional testing approach, in which a transceiver unit generates an RF signal that goes into an antenna array that converts the cable-based RF signal into an over-the-air radiated signal. Passive antenna testing is straightforward, as the antenna under test (AUT) can be fed with an RF input and you measure the RF output. Comparison is possible.

To be more flexible and allow some centralization of signal generation, new trends are emerging that integrate some physical layer behavior into the antenna itself. Future antenna arrays may be active; i.e., a digital interface as the input with most RF signal generation steps performed in the antenna. The difficulty is that some of these digital interfaces; i.e., CPRI, may be vendor specific and therefore difficult to access. One key challenge is how to obtain the phase information if the input signal into the AUT is unknown? Currently there are no technical solutions to perform EVM measurements in the near field if your antenna is an active antenna system. Some possible workarounds are to steer a beam by using a smaller number of antenna elements to “physically” reduce the aperture size, creating a far field scenario.

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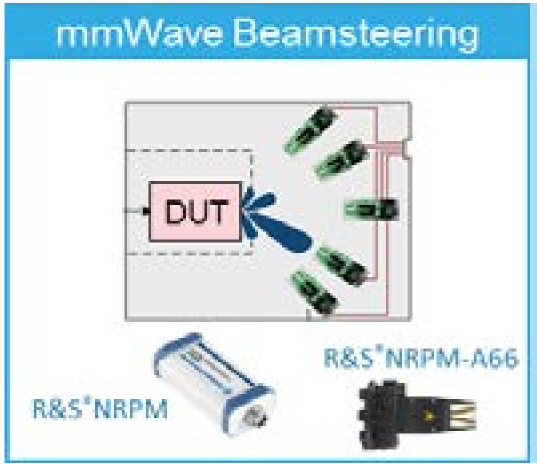
# What is the right OTA test solution for my application?

When talking about over-the-air (OTA) test solutions and methods, there is not “one size that fits all.” OTA testing addresses a wide range of applications, in which we need to take in to account technical issues such as near field, far field, frequency, antenna type etc. And from a design cycle perspective, the OTA test configuration and tests will differ considerably depending on whether we are testing in R&D, manufacturing or in field deployment. In the future, new application areas like beamforming certification and verification or production oriented testing solutions will appear and evolve to meet various capability needs whether that be high accuracy, speed, cost, etc. Currently in the 3GPP meetings, we are discussing a method to characterize a beam based on a vendor-specific declaration of five power level points (center point = max power, 2 points left and right, 2 points top and bottom). One possible test solution that addresses this testing need is a power sensor based solution as shown.

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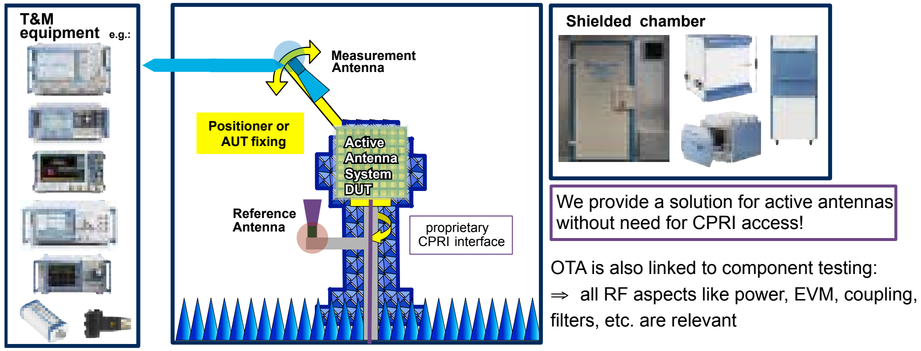
# What equipment is needed for OTA measurements?

As discussed earlier, OTA testing comprises a wide range of test applications. Rohde & Schwarz has the widest range of products covering chambers, test equipment and software. A "one-stop-shop" when it comes to OTA testing. In general, there are four key components to any OTA measurement system:




**Shielded chamber:** various sizes required (near field and far field aspects); shielding capability, chamber mobility, access, etc.

**Measurement antenna:** frequency range and size are key considerations.

**AUT fixture or positioner:** OTA testing requires accurate and reproducible results, which requires that the AUT and measurement antenna must be tightly secured at a known location for both calibration and measurements. In some cases, there are multiple antennas mounted in an antenna ring configuration or in other cases one measurement antenna is used with a moving positioner. Positioner precision is a must have for accurate results – especially in the case of near field measurements in which the data needs to be transformed into the far field.

**T&M equipment:** Depending on the above topics, many different types of test and measurement equipment may be used for OTA testing. Some frequently used equipment may include: vector network analyzer, signal generator, signal analyzer, mobile radio communications tester, oscilloscope, power sensors, etc.

**Note:** for active antennas it may be necessary to get access to the optical interface - or use a solution that does not require CPRI access.

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