STARWAVE

Shaping the future of 5G mmWave OTA testing

Introducing StarWave, a compact, accurate and flexible far-field OTA testing solution for 5G devices

MVG
Microwave Vision Group

TABLE OF CONTENTS

Shaping a connected society with 5G

The dawn of 5G is upon us and unlike transitioning between previous generations of mobile networks, this will be an all-encompassing global leap towards a digitally enhanced, completely connected, largely automated way of living. It is, to all intents and purposes, a dramatic overhaul and harmonization of the radio spectrum.

This networked society promises revolutionary improvements in data rates and latency, as well as considerably enhanced network capacity and notable reductions in operational and infrastructure costs for network operators. However, realizing and meeting the evolving needs of such developments requires complete radical change of how we, as an industry, design, develop and test an ever-broadening portfolio of 5G devices.

WIRELESS CAPABILITY

The fundamental component for 5G success

Realizing the global 5G vision depends on delivering efficient and powerful wireless connectivity – without that, the expectations and seemingly limitless ability of 5G are lost. And it is for that reason, best practice antenna testing of any 5G device, great or small, is to be optimized.

This brochure will explore the theme of effective, best practice 5G device testing with a keen focus on direct far-field testing to mark the launch of StarWave by MVG, a dual-polarized, wideband plane wave generator for the compact, flexible, fast and accurate direct far-field OTA testing of 5G antennas.

The dawn of 5G antenna testing and its key challenges

The magnitude of what is deemed capable as we face the dawn of 5G is nothing short of inspiring, with autonomous factories and agricultural processes, self-driving cars, the convenience and comfort of a connected home, and even remote medical surgeries.

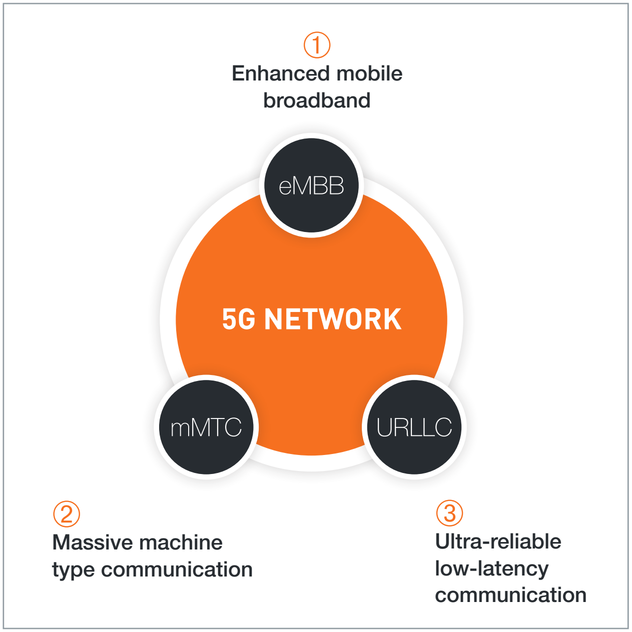
Concepts such as these demonstrate the critical importance of full-system performance testing and, in particular, the accurate evaluation and analysis of antenna testing in order to deliver the wireless connection required for such revolutionary applications.

To better understand the OTA testing challenges for the 5G network, it is vital to first appreciate the three cornerstones of 5G development:

① Enhanced mobile broadband speed and capacity
Increased bandwidth and capacity for mobile data able to handle the ever-increasing amounts of wireless data traffic.

② Scalability for massive data and Internet of Things
Reduced overheads for massive applications such as sensor networks consuming very little bandwidth and power.

③ Ultra-reliability, low-latency for mission critical services
Real time critical connectivity such as self-driving cars, robotics, automated factories and medical applications.



WHAT ARE THE FOUR KEY CHALLENGES TO 5G OTA TESTING?

CHALLENGE ONE: Dynamically steerable beams and the evolution towards Massive MIMO BTS

Unlike previous generations of telecommunications standards, 5G uses dynamically steerable beams which maximize connectivity by directing as much of the signal toward the device as possible. This shift eliminates traditional antenna testing methods, whereby a device is evaluated once over a full sphere in order to measure its total sensitivity and total radiated power.

These steerable beams are created by phased array antennas which need to be calibrated and measured in a large number of configurations to ensure the connectivity of the device is adequate.

To make steerable beams a viable and reliable method of transmission, base transceiver station (BTS) antennas are evolving from passive antenna to active antenna systems (AAS) with the integration of the remote radio head. The most favored AAS is the Massive MIMO concept, which many providers are already evolving towards in order to multiply the capacity of a wireless connection without the need for increased spectrum.

CHALLENGE TWO: Wide bandwidths and mmWave frequencies

To allow higher throughput and fully realize the 5G vision will mean harnessing the power of spectrum which has, until now, been 'untapped'. Whilst additional spectrum below 6 GHz has already been allocated for cellular communications in some countries, much larger contiguous spectrum has been identified for 5G evolution in the centimeter and millimeter-wave (mmWave) bands above 24 GHz; with frequency bands around 28 GHz and 39 GHz fueling the majority of 5G NR development at the present time.

Introducing mmWave devices into our telecommunications network poses a number of testing challenges. The higher frequencies and the RF architecture within 5G devices eliminate the possibility for RF connectors and lab-based performance testing, with the industry now turning to Over-The-Air alternative test methods for RF system performance, radio resource management parameters and antenna testing. 3GPP has outlined OTA testing for conformance testing of mmWave user equipment and base stations (BTS)[1]. To date, three OTA testing methodologies have been approved by 3GPP, direct far-field, indirect far-field and near-field to far-field transformation[2].

CHALLENGE THREE: mmWave omni-directional antenna OTA testing

Due to their size and limited number of embedded antennas, 5G devices present radiation patterns that remain mainly omni-directional, at least in one plane. Measuring mmWave omni-directional antennas requires a smart setup to optimize the acquired data accuracy. No matter the quality of the radiocom tester, the communication channel is largely limited by the operational test setup. **No solution on the market today offers accurate far-field OTA testing conditions for mmWave devices.**

CHALLENGE FOUR: Live end-to-end testing of a device while being worn and/or operated by a user

Live testing of devices in general is absolutely mandatory - A device cannot be launched to market unless it has been extensively tested in realistic conditions. This is even more true for 5G FR2 where ultra-reliability of the connetion is mandatory. At those frequencies, the human body easily absorbs eletromagnetic waves and can greatly modify the lab-measured/theoretical radiation pattern of the embedded antenna. Hence, the connectivity performances of the device can be highly impacted. But at mmWave frequencies, it is not possible to test those performances in near-field conditions – the slightest movement, like a person breathing, will impact the quality of the measurements and hence the accuracy of test results. Therefore, testing in far-field is the only available option. However, the test conditions must also be able to take into account humans under test with a device, not only phantoms. **Today, the products available on the market are not able to provide live end-to-end testing solution.**

1 the references for conformance testing are 3GPP TR 38.810, 3GPP TS 38.521-2 (SA- Standalone), 3GPP TS 38.521-3 (NSA- Non-standalone), and 3GPP TS 38.903. (https://www.3gpp.org/ftp/Specs/latest/Rel-16/38_series)
2 March 2019, "Test & Measurement Industry Tackles 5G Over-the-Air Testing", Microwave Journal, Issue 62, Page 20-38

Best practice for 5G mmWave OTA testing

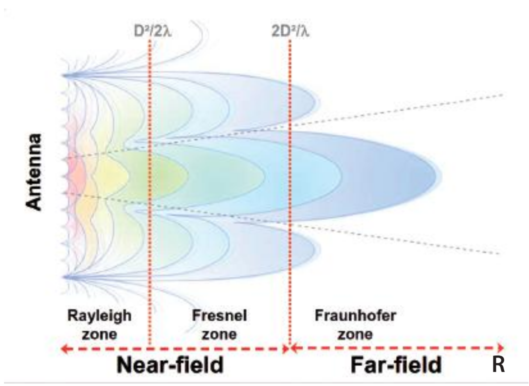
5G devices require an over-the-air (OTA) test method which creates a number of challenges in both the near-field and far-field when testing the latest antenna technology.

5G testing in the near-field may benefit from smaller chamber sizes. Nevertheless, the near-field technique does not allow for measurement of some performance parameters such as the Error Vector Magnitude (EVM) figure, according to the standard procedure today. In addition, the near-field technique requires near-field to far-field transformation and depends on phase and magnitude readings which are challenging for modulated signals.

Direct far-field testing, whilst capable of delivering magnitude data, is, at such high bandwidths, a space-hungry test method, (see table far-field distance) thus financially prohibitive, which renders it an unsuitable solution for many manufacturers.

In other words, when measuring a regular smartphone for example, which measures approximately 15 cm in size, using the far-field Fraunhofer distance equation, we can denote that the far-field distance and therefore the size of the required anechoic chamber will increase dramatically with antenna size and frequency, requiring a far-field distance of between 4.2 m and 5.9 m. See far-field distance table.

Field region



D = The minimum diameter of the sphere enclosing the antenna
λmin = The wavelength of the highest frequency measured
R = Measurement far-field distance $> 2D^2 / \lambda$min

Far-field distance R (m)

Device size (cm)	Frequency 28 GHz	39 GHz
5	0.5	0.7
10	1.9	2.6
15	4.2	5.9
20	7.5	10.4
25	11.7	16.3
30	16.8	23.4

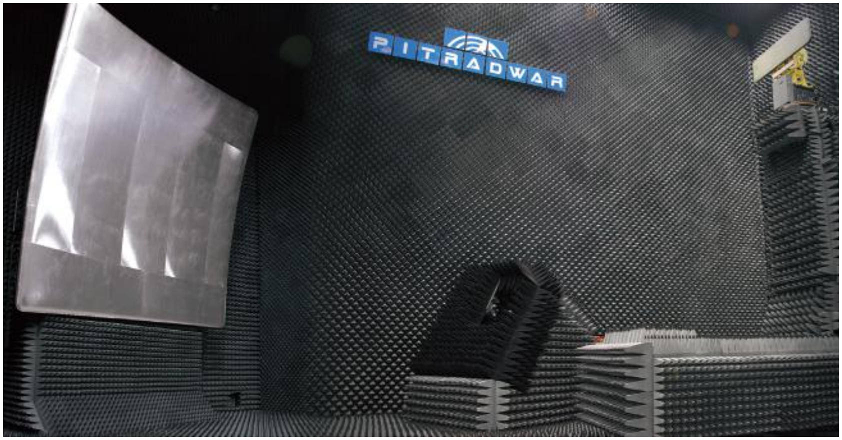
In conclusion, best practice theory recommends 5G OTA testing of antennas under far-field conditions, which, given the expansive nature of such test facilities, poses the question: How to perform OTA testing in far-field conditions facing the four challenges mentioned previously?

COMPACT ANTENNA TEST RANGE (CATR)

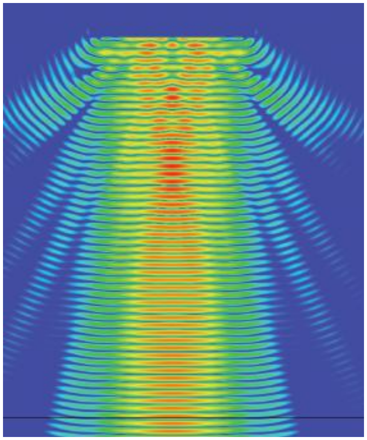
Well known in the industry, this method approximates a plane wave in the QZ in which the amplitude and phase variation is below a user-specific tolerance. A CATR allows electrically large antennas to be measured at a significantly shorter distance than would be necessary in a traditional far-field test range. Compact ranges use a source antenna (feed) to radiate a spherical wave in the direction of a parabolic reflector, collimating it into a planar wave for aperture illumination of a Device Under Test (DUT).

PLANE WAVE GENERATOR (PWG)

A Plane Wave Generator (PWG) is an array of elements with suitably optimized complex coefficients, generating a plane wave over a finite testing volume (the quiet zone). The PWG enables direct measurements of far-field performance of the DUT in a controlled indoor environment as an alternative to CATR.

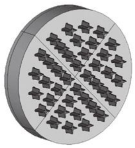
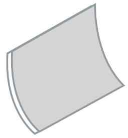


MVG compact antenna test range - A full turnkey solution made for PitRadwar



Example of PWG radiating pattern

PROS AND CONS OF THE CURRENT METHODS: PWG VS CATR

				
Comparison Parameter	**Generic PWG**		**Generic Compact Antenna Test Range (CATR)**	
Size of Radiating Surface	1.1*QZ	🙂	1.5*QZ	😐
Distance to QZ from the Radiating Surface	~1.5-2*QZ	🙂	~5*QZ	😠
Spill-over from Feed	N/A	🙂	Yes	😐
QZ Uniformity	Yes	🙂	Yes	🙂
Wideband Operation	Yes	😐	Yes	🙂
Dual Polarisation	Yes	🙂	Yes	🙂
Live End-to-End Testing	No	😠	No	😠
High Directivity Antenna	Yes	🙂	Yes	🙂
Low/ Medium Directivity Antenna	No	😠	No	😠
Large DUT Size	Yes	😐	Yes	🙂

The table above shows the advantages and disadvantages of the existing testing methodologies. Neither of them meets all four challenges of 5G mmWave OTA testing.

To meet the evolving needs of the telecom industry, MVG has developed an innovative testing solution.

PATENT PENDING

INTRODUCING STARWAVE *BY MVG*

A new era of 5G mmWave OTA testing

MVG brings to market a new generation of 5G mmWave OTA testing solutions, combining smart mechanical positioners with PWGs to create accurate direct far-field conditions in a compact system.

StarWave, is composed of one or several (up to seven) PWG(s) attached at a 90° angle to a vertical disk, which rotates. In front of the disk, an electromagnetically transparent mast is mounted on an azimuth positioner to support and rotate a DUT. The interface used between the mast and the DUT depends on the device, with the possibility of inserting a chair for a person holding a device.

StarWave rotates the plane wave generator(s) around the device or antenna under test to perform the elevation plane measurement. The DUT/AUT can turn in azimuth on the mast to perform the azimuth plane measurement*. The combined movements of the PWG and the DUT achieve a measurement on a complete sphere around the DUT with a minimum truncation area. This configuration improves test speed and accuracy of OTA testing. This set up also allows a device to be end-to-end tested while being worn and/or operated by a user, either standing or sitting.

Composed of hundreds of elements, the PWG has been specifically designed to create a QZ in front of its radiating surface at a distance corresponding to the radius of StarWave. The diameter of the QZ is given according to a set of parameters of the PWG. The PWG has been designed to allow wideband signal measurement and is dual-polarized for fast, accurate measurement of antenna performance criteria.

The most compact solution brought to market, StarWave offers flexible, accurate and efficient testing of 5G devices.

* Optionally. StarWave can be mounted on a turntable and rotated directly around a stationary DUT.

KEY TAKEAWAYS

❶ Smart positioner system – fast and simple

The multi-axis positioning systems used for 3D radiation pattern measurements in far-field and CATR systems are not well suited for low gain antenna measurements. StarWave rotates the PWG in elevation around the DUT, using only a single-axis azimuth positioner for the DUT. This enables 3D measurement of 5G devices with medium or low gain antennas with minimum scattering caused by the positioning system, resulting in more accurate measurements.

❷ Efficient operation

Mounting the DUT on the flat-top interface of the positioner mast is fast and easy as the DUT rotation is azimuth only.

❸ Live end-to-end testing

Devices can also be end-to-end tested while being worn or/and operated by a person.

❹ A single testing solution for all your antennas

Scalable to suit different devices and capable of accurately testing all 5G bands, eliminating the need for multiple testing solutions.

❺ Minimal electronic parts for stable operation

Designed and constructed with few electronic components, sensitivity to temperature fluctuations is minimized for the stability of operation and ease of maintenance.

❻ Test multiple frequency bands at once

Choose to test different bands at the same time with several plane wave generators surrounding the DUT.

❼ The perfect setup for MIMO environment testing

Up to seven plane wave generators can be mounted on StarWave for MIMO testing to simulate multiple paths.

❽ Flexible design options to suit your requirement

A scalable, flexible system design means MVG can work with you to deliver a Starwave system customized for your testing requirements.

StarWave FR1 and StarWave FR2 simplified specifications

Full spherical measurement system in direct FF conditions according to 3GPP IFF specification

Number of PWGs supported:	Maximum 7, with angular separation at 45°
Anechoic chamber size:	4 x 4 x 4 (m)
External radius of rotating PWG:	1475 mm
Future options:	3D stereo camera for CAD generation and interface with post-processing/ simulation tools or understand the coordinate system of the device that you are testing.
	StarWave can be mounted on a turntable and rotated around a stationary DUT.

PWG simplified specifications*

Model 1: PWG6 I Coming soon
Compatible with StarWave FR1 and StarWave FR2

Frequency band:	600 MHz – 6 GHz

Model 2: PWG28 I Available now
Compatible with StarWave FR2

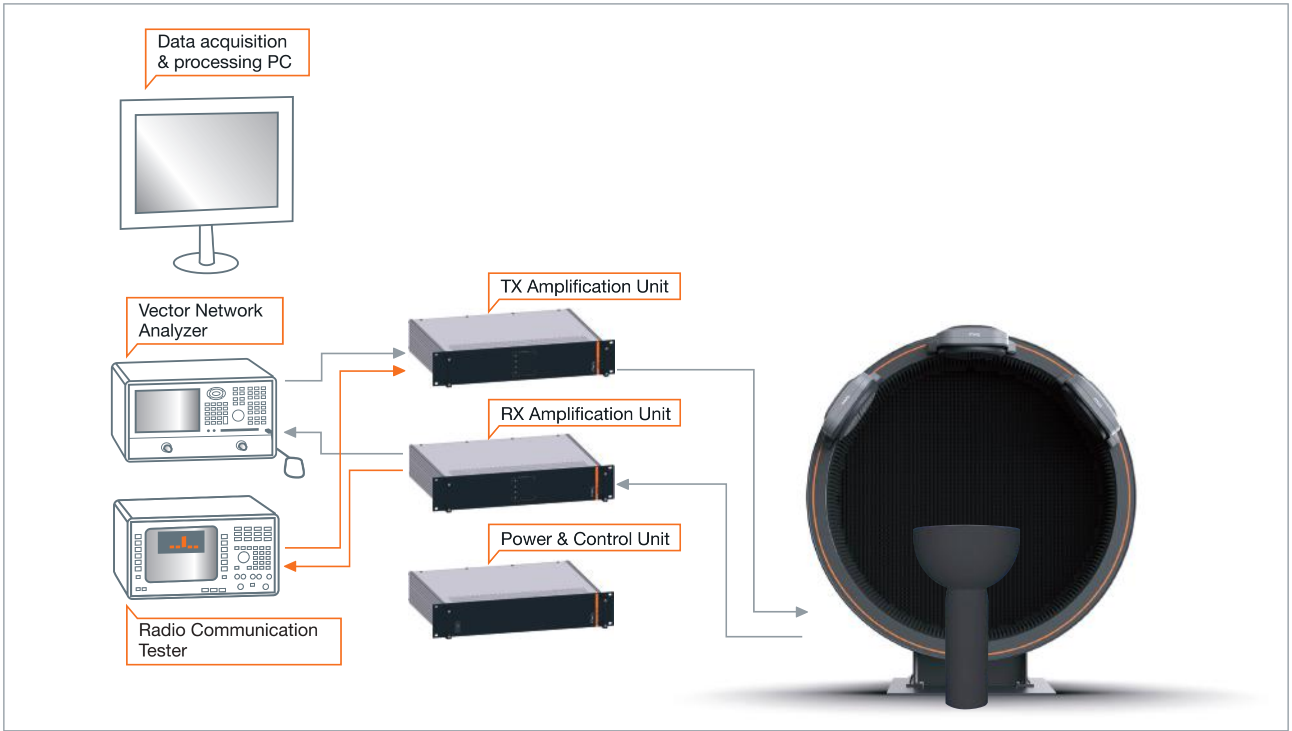
Number of elements:	> 100
Frequency band:	24.25 GHz – 29.5 GHz
Measurement distance:	1200 mm
Quite Zone (QZ):	350 mm – 380 mm

Model 3: PWG39 I Under development
Compatible with StarWave FR2

Frequency band:	Around 39 GHz - tbd

*More PWGs could be added to cover other 5G frequency testing needs.

SYSTEM OVERVIEW



StarWave parameters at a glance			
Size of Radiating Surface	🙂	**Live end-to-end testing**	🙂
Distance to QZ from the Radiating Surface	🙂	**High Directivity Antenna**	🙂
QZ Uniformity	🙂	**Low/ Medium Directivity Antenna**	🙂
Wideband Operation	😐	**Large DUT Size**	😐
Dual Polarisation	🙂	**Smart Positioning System**	🙂

A CLOSER LOOK AT STARWAVE

Proven credentials – StarWave under test

PWG28 SIMULATION RESULTS

MVG has proven the credentials of its StarWave PWG, a dual-polarized wideband PWG for direct far-field testing conditions, covering the 24.25 GHz to 29.5 GHz range (PWG28).

Amplitude and phase variation

The simulation test shown here presents the result of the PWG28 spherical QZ. It presents a diameter of 350 mm centered at a distance of 1200 mm from the array aperture.

The reported values of amplitude and phase variation within the entire QZ volume are extremely low on the whole frequency band, demonstrating the quality of the plane wave generation achieved, as shown in the figures.

PWG28 simulation figures - In the 2D views, the QZ is represented by a white circle. In the cuts, the QZ is represent in the white area. The simulation shows minimum amplitude and phase variation in the QZ area.

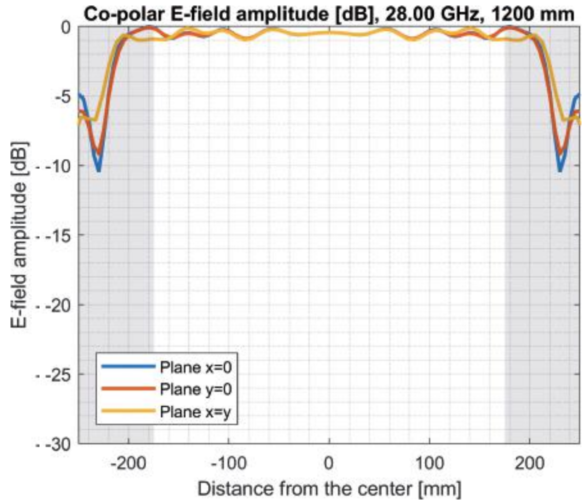


Figure 1

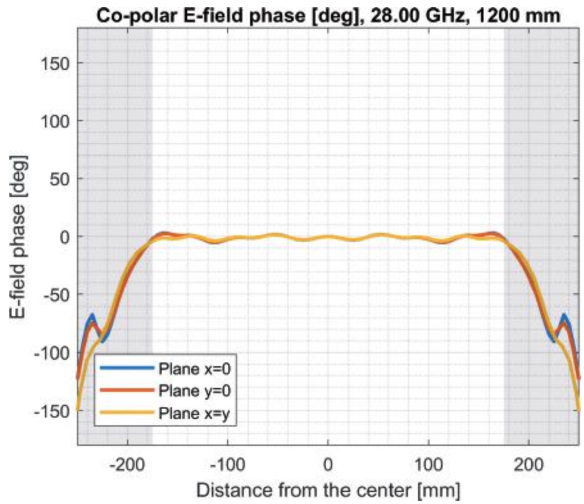


Figure 3

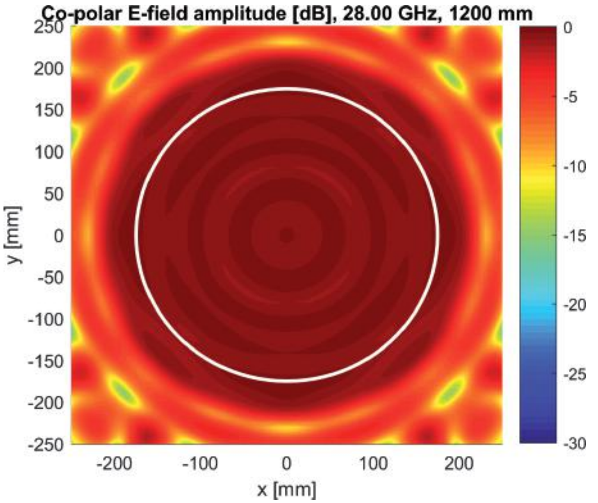


Figure 2

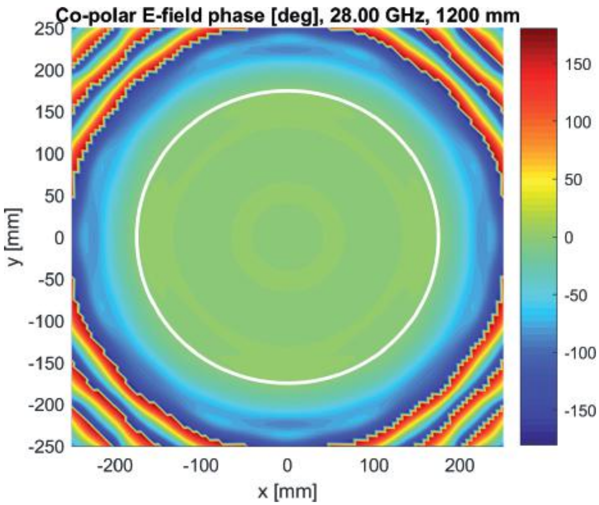


Figure 4

COMPARISON AMONG STARWAVE, STARLAB 50 GHz AND SIMULATION

To demonstrate the ability of StarWave to measure semi-directive devices, MVG chose its well-known QR18000, a closed boundary quad-ridge horn, operating between 10 and 40 GHz. This horn (see figure 5) presents a typical medium gain antenna radiation pattern (see figure 6 and 7).

Figure 5

Typical 3D co-polarization radiation pattern

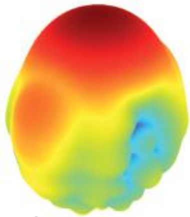


Figure 6

Typical 3D cross-polarization radiation pattern

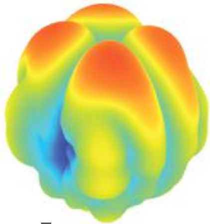


Figure 7

A measurement campaign was performed to compare measurements of QR18000 @28 GHz in StarWave and StarLab 50 GHz. Figure 8 shows the comparison between the two measurements along with a full wave simulation and shows an excellent correlation among the three curves. It proves the capability of StarWave to perform low to medium gain antenna measurement at mmWave frequencies.

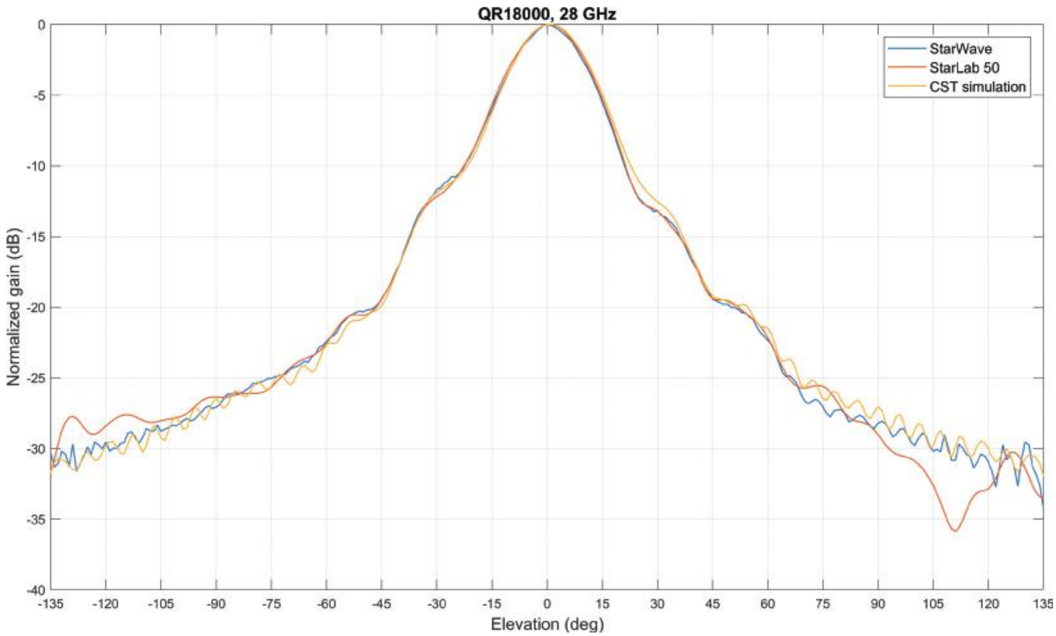


Figure 8

REFERENCE

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3. A. Scannavini, F. Saccardi, L. J. Foged (MVG Italy), Kun Zhao (Aalborg University). Impact of Phase Curvature on Measuring 5G Millimeter Wave Devices. https://www.mvg-world.com/fr/resources/technical-paper/impact-phase-curvature-measuring-5g-millimeter-wave-devices

MVG STARWAVE OPTIMIZES 5G DEVICE TESTING PROCESSES

This compact and flexible, dual polarized, wideband plane wave generator turn-key test system was developed to improve testing efficiency and optimize time-to-market of 5G devices.

Call our dedicated team of specialists today to discuss your specific requirements and how StarWave could be what you are looking for next.

Testing Connectivity for a Wireless World

The Microwave Vision Group (MVG) has developed unique expertise in the visualization of electromagnetic waves. These waves are at the heart of our daily lives: smartphones, computers, tablets, cars, trains, planes - these devices and vehicles would not work without them. MVG expertise brings measurement solutions to R&D teams for the characterization of antennas and their performance within these devices, and chamber solutions for EMC testing. MVG innovation remains focused on supplying the world with the most advanced EMF measurement technology to date.

WORLDWIDE GROUP, LOCAL SUPPORT

Our teams, in offices around the world, guide and support you from purchase, through design, to delivery and installation. Because we are local, we can assure speed and attention in project follow through. This includes customer support and maintenance once the system is in place. For the exact addresses and up-to-date contact information: **https://www.mvg-world.com/contact**

Contact your local sales representative for more information
salesteam@mvg-world.com
https://www.mvg-world.com/StarWave