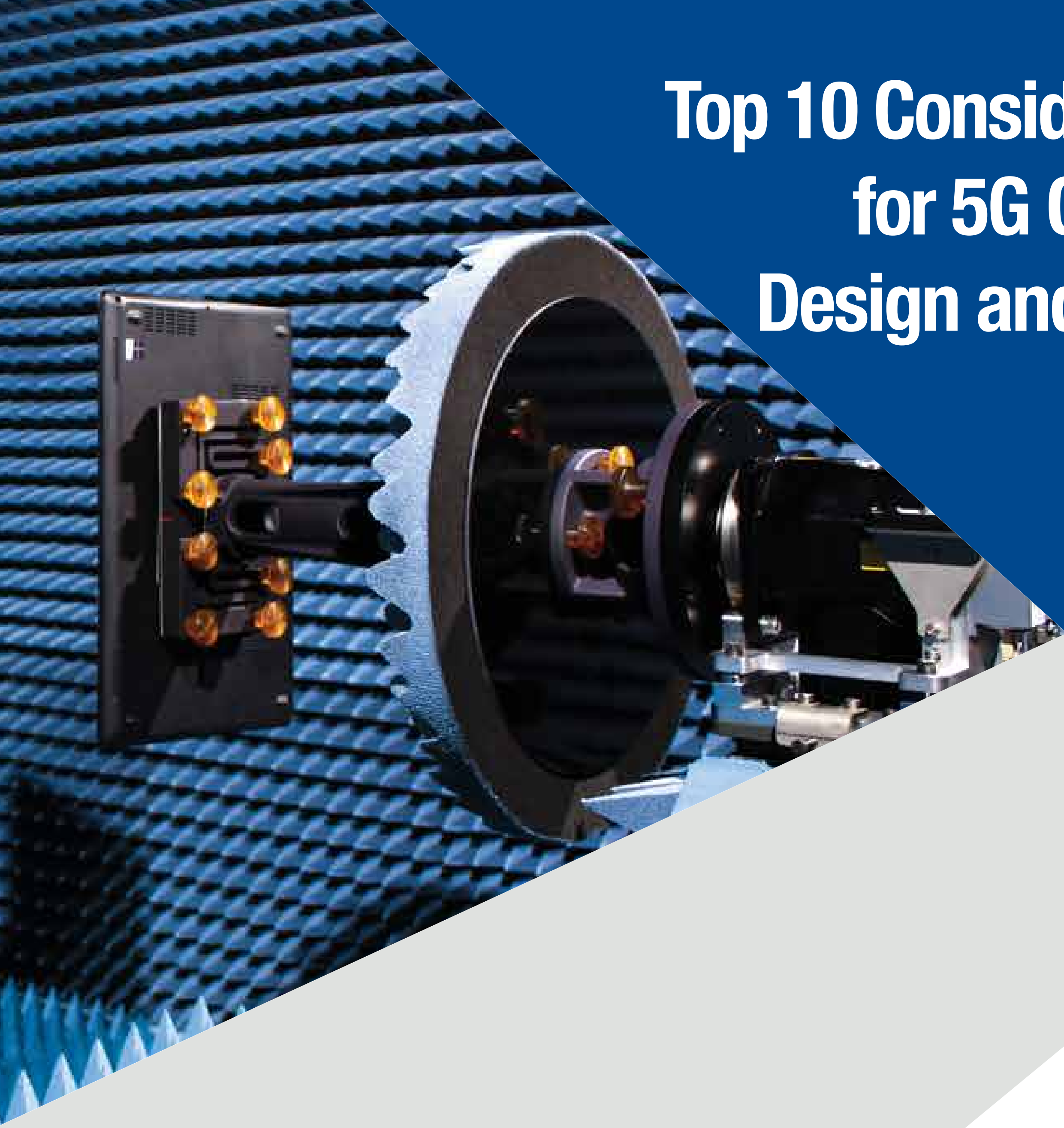

Top 10 Considerations for 5G Chamber Design and Testing

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TOP 10 CONSIDERATIONS FOR 5G WIRELESS CHAMBER DESIGN AND TESTING

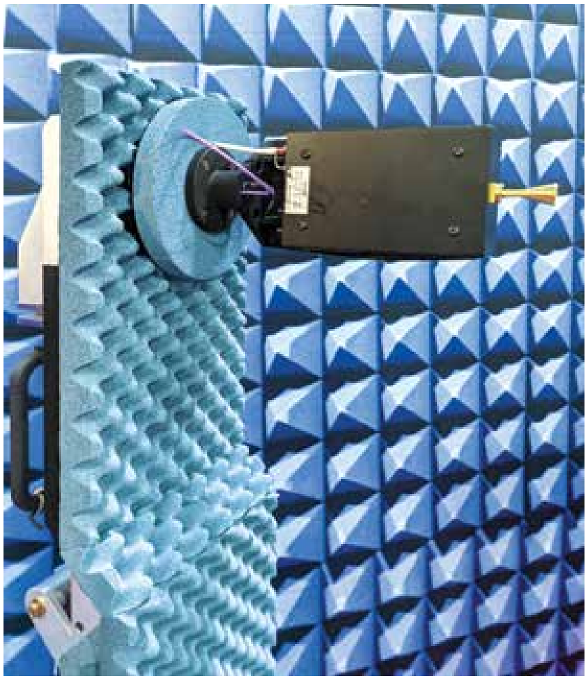
Following is our Top 10 list of the most important factors to consider when developing or refining your requirements for a 5G wireless test chamber. We hope this resource helps you avoid common mistakes and identify important details that will ensure a successful project outcome. A wireless test chamber is a significant investment. Protect your chamber through awareness of factors that will contribute to, or may adversely impact, a positive return on your investment. Quick and concise, this guide covers pre-delivery preparedness, standards awareness, understanding of FR1 and FR2 testing, nuances of reflectors, upgrades to your existing chamber to expand testing capabilities, the critical impact of software, emerging industry trends – including base stations and phased arrays – and more! Whether yours is a commercial test lab or a company looking to expanding its in-house R&D capabilities, these considerations should help you arrive at the optimal chamber design to address your wireless test needs now, and in the future.

1. Are 5G OTA Test System Upgrades Possible?

The most common question surrounding 5G is: "Can my current test system support it?" Your studies have likely identified that far more tests must be done over-the-air (OTA) rather than conducted as with past generations. The antenna systems used in 5G are active and have a much larger impact on device performance and must be included in the measurement. So expect a much heavier load to be carried by the OTA test system in 5G.

5G FR1 SISO tests might push the frequency range boundaries on some systems. The FR1 band is expanding lower to 410 MHz and higher to 7.125 GHz. Other technologies like 802.11ax and its expansion to Wi-Fi 6E are also targeting the newly opened spectrum from 5.925 to 7.125 GHz for consumer non-licensed transmissions, meaning upgrades to the chamber might be necessary. The 6 GHz transmission band will stress most instrumentation as well, with the majority of network and channel emulators needing some way to stretch beyond 6 GHz as the upper frequency. If you are planning new OTA chambers, make sure to cover this expanded FR1 band. To upgrade existing chambers and instrumentation, plan on potentially significant time and investment to complete the RF upgrades. An experienced wireless test chamber supplier can help guide you through this process to evaluate the cost/benefit trade-off to upgrade an existing chamber or invest in a new chamber.

Often, we are asked if FR1 chambers can be upgraded to support FR2. In some cases, it may be possible in chambers with short distances between the device under test (DUT) and the measurement antenna. But systems with range lengths longer than about 2 m (6.5 ft) won't have the dynamic range necessary due to free-space path loss at 28 and 39 GHz. The favored approach for FR2 is the compact antenna test range, or CATR.



2. Remember to Validate the Site Specifics for Your Test Chamber Installation – Before You Place an Order.

It's easy to get carried away with the prospect of a new test chamber and the exciting test capabilities it will offer. However, careful deliberation of placement inside the host building is called for very early in the design process. You will want to avoid the sinking feeling that comes with the realization that your new chamber height won't fit in the allocated space when the materials arrive on-site. Ceiling height is a very common limitation, with most chambers necessitating 3 to 4.5 m (10 to 15 ft) of clear space under any obstruction. Another commonly overlooked issue is the pathway from the delivery truck to the installation site. The best approach is to thoroughly trace this path with a tape measure and the measurements of the largest assembly for your chamber, often the chamber door frame or shielding panel. If the site will not be located on a ground floor, is a freight elevator with adequate weight capacity and dimensions easily accessible from the loading dock? Is there a weight capacity limit on upper floors? Are all hallways wide enough, with special attention paid to hallway angles and tight corners? During the pathway trace, also watch for lighting, signs, plumbing/fire sprinklers, and HVAC duct work that could impede the path to the chamber installation site. Double doors may have a center pillar or closing mechanism that could restrict wide loads; doorjambs may also hinder passage. Are regional seismic requirements applicable to the installation site? When you walk the path, we guarantee you will discover things you have never noticed before!

For preassembled, portable test chambers, areas where the chamber will ideally be used also need to be analyzed. For example, can the chamber fit around lab benches and through the doors between the labs? Is the pathway straight from one lab to another, or is there a turn that may cause an issue? Will an elevator be necessary to move the chamber from one floor to another? If so, verify that the chamber can fit into the elevator and the chamber weight complies with the elevator weight restrictions. Is a power drop of sufficient voltage and current available at both sites? These are all considerations to take into account upfront to avoid surprises such as potential cost overruns and subsequent schedule delays when preparing for a chamber installation.

For planning assistance, you may want to consider using Building Information Modeling (BIM), the current tool of choice for architects. BIM experts can design a virtual model to physically visualize a completed project before it begins. The process results in a reduction of reworks, change orders, construction delays, and unnecessary expenses. It provides 3D representations of not only the architecture, but also the mechanical, electrical, and plumbing. It's a great collaborative tool that delivers the confidence and ultimate results you want in protecting your investment. When considering BIM, ensure your supplier uses in-house, certified BIM technicians for your project, as they are the most familiar with and have the most experience in modeling your chamber. Some chamber suppliers out-source or subcontract BIM services, which may increase your risk of receiving a less-than thorough or inconclusive model of your project. When in doubt, ask your chamber supplier to document their BIM experience.

3. Understand the Nuances of a Compact Antenna Test Range – Not All Are Created Equal.

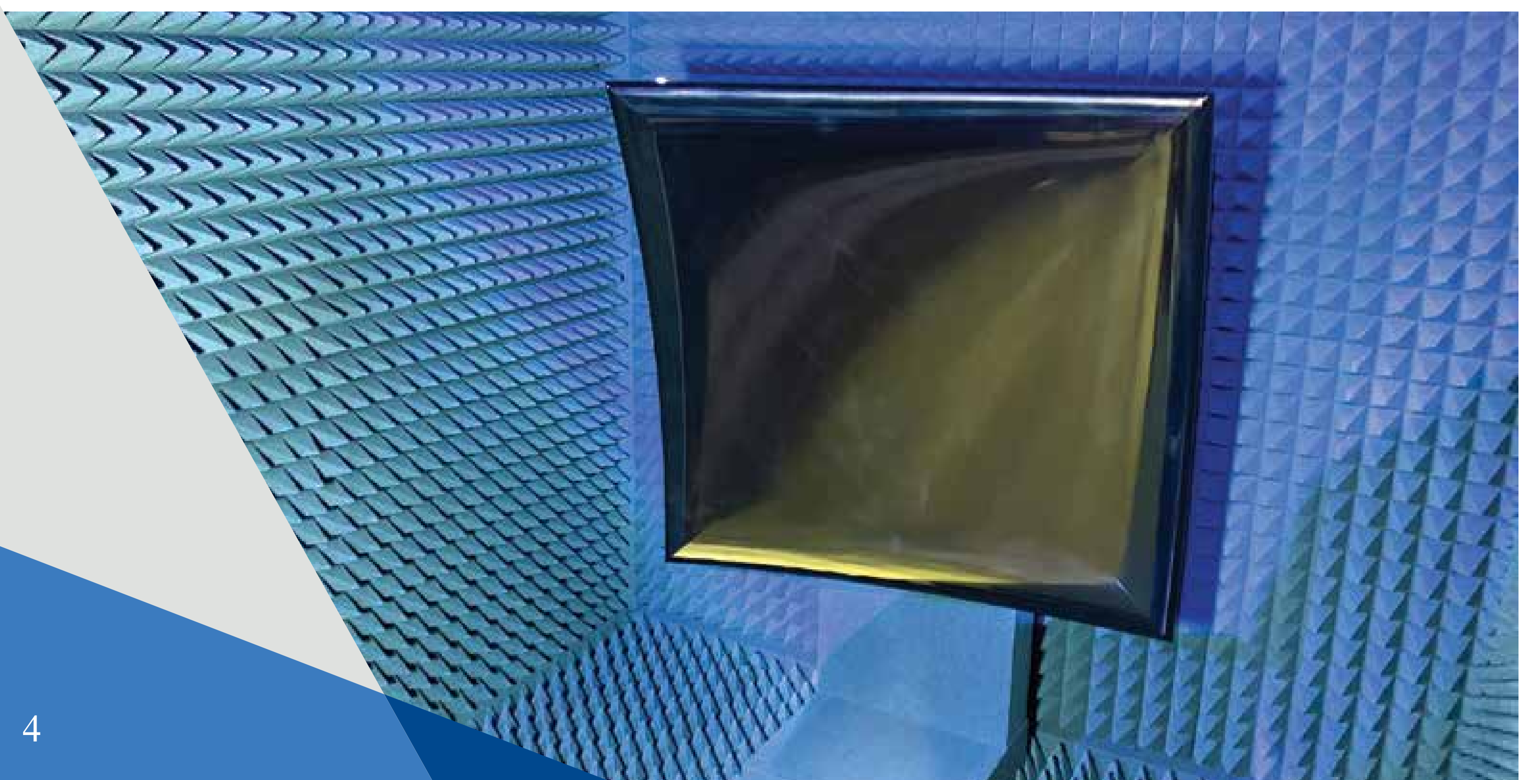
Compact ranges, or CATRs, are the favored environment for FR2 testing and have different specifications for quiet-zone performance; also, the source of impairments is different from FR1. CATRs use a parabolic reflector to focus the energy of the transmission to achieve a plane wave in a much shorter range than would be normally needed by the wavelength of the transmission. When comparing CATRs, key specifications include amplitude and phase taper, which describe the accuracy of the reflector shape and overall system performance of absorber and feed horn alignment. We expand on this topic in Section 5 on page 6.

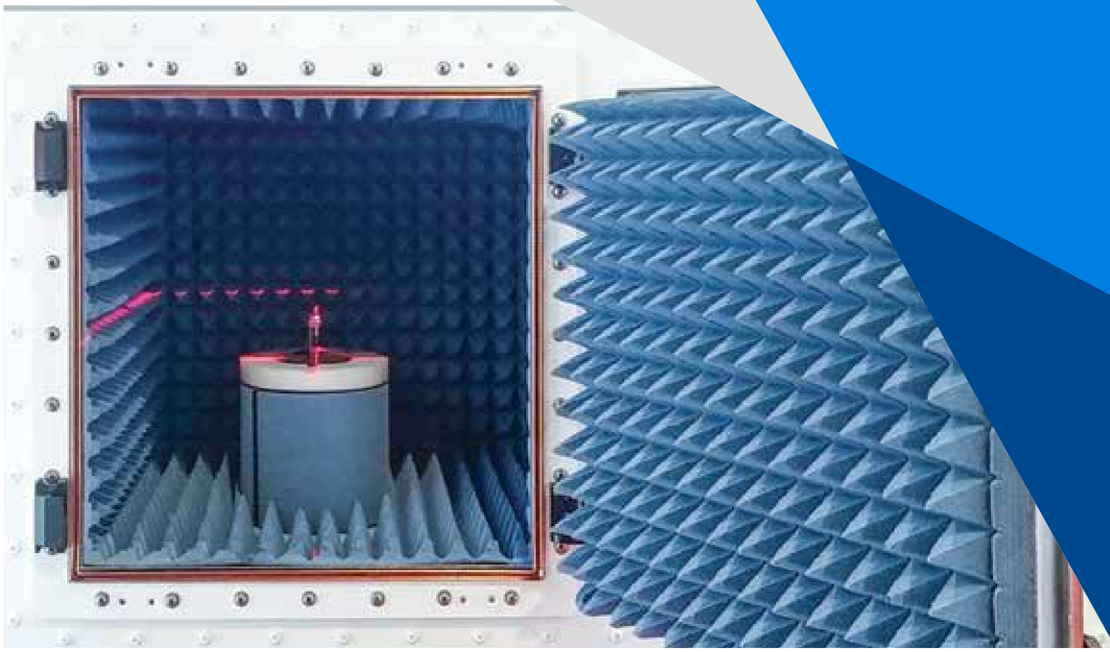
Shielding effectiveness, or how well outside signals are kept outside and inside signals are kept inside the chamber, is another prominent specification, though not such an important issue for 5G FR2 CATRs, since signals at this frequency bounce off nearly any surface. Free-space path loss at 28 and 39 GHz is also high, and the signals are highly directional, so the chances a signal outside the chamber will inadvertently find a path inside the chamber at an amplitude that could impact the test is very low.

Positioning accuracy, however, becomes much more important for a CATR versus an FR1 chamber. An important FR2 transmission requirement is beam lock, or halting the active beam steering function on the device. Finding the beam peak is a requisite for most tests and demands precise device movements of a few millimeters, or less than 1 degree on a sphere around the device. Since most CATRs utilize dual axis positioners to provide 3-dimensional antenna patterns, all movements must have sub-degree precision.

The parabolic reflector is the most important component of any CATR. Reflectors can be made from various stiff materials such as metal or carbon fiber. The edge finishes, whether rolled or serrated, are critical to controlling distortions of the waveform. Both approaches work well at redirecting the distorted edge portion of the waveform to the surrounding absorber and away from the quiet zone where it would cause amplitude ripple. Most reflectors are milled to the precise shape necessary before being polished. The finished roughness of the reflector surface sets the upper frequency range. Surface variations cause distortions to the focus and, at some point, the wavelength of the signal approaches the size of the variations. Reflectors capable of 100 GHz or higher are common for FR2 CATRs. A poorly shaped or polished reflector, or one without adequate edge control, will impose limits to the frequency range or usable quiet zone. Section 5 discusses how this is measured.

In short, pay close attention to the reflector proposed for your CATR. If the reflector is not properly made, your measurement will not be as accurate. Not all reflectors are created equal.





4. What Size Quiet Zone Do I Need?

Wireless carriers are confident that 5G will spread wireless data capability far beyond the smart phone case that drove LTE's success. To justify building out 5G capability, carriers expect machine-to-machine use cases to drive hundreds more connections per base station. The machines could be vehicles receiving real-time road condition updates, homes or businesses having fixed wireless access, augmented virtual reality (VR) glasses displaying stereoscopic images, increasingly sophisticated infotainment devices, or gadgets collecting sensor data important enough to track. The implication is that form factors larger than smart phones are sure to be manufactured and will require testing.

Current 3GPP test cases are free space, but CTIA Certification™ will carry forward the use of phantoms to closer represent the actual user experience. CTIA Certification has shown a willingness to develop phantoms far beyond head and hands to simulate the real-world impact to the user experience. Phantoms, or mounts, that mimic a car roof panel, a full head wearing VR goggles, or a glass-mounted directional antenna are all possibilities. The DUT, mounting assemblies, and phantoms must each fit within the quiet zone.

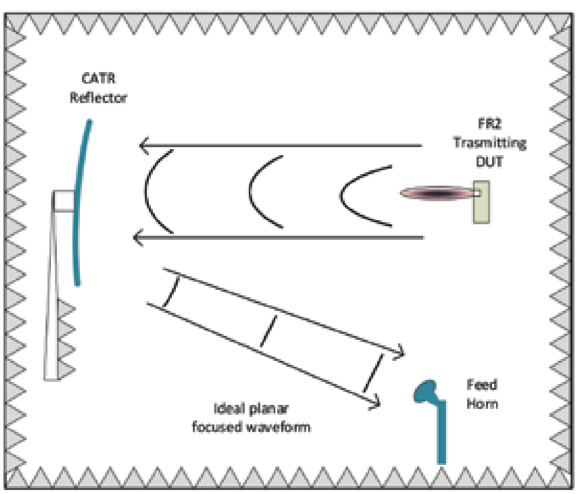
FR1 chambers can likely accommodate whatever CTIA Certification might deem necessary, but some caution is warranted in FR2. The market for 5G FR2-centered compact ranges mostly specify a 30 cm (12 in) quiet zone. Devices larger than a tablet computer may fall outside this range, especially if phantoms or a special mount is necessary. CATRs with quiet zones of 45 cm or 60 cm (18 in or 24 in) would be safer if your lab is able to handle larger devices. For small-cell base stations or specialty devices, CATRs with quiet zones up to 150 cm (59 in) are available from some test solution providers. Independent test labs should consider a 60 cm (24 in) quiet zone walk-in CATR, as this should handle just about every form factor device that strolls into your lab.

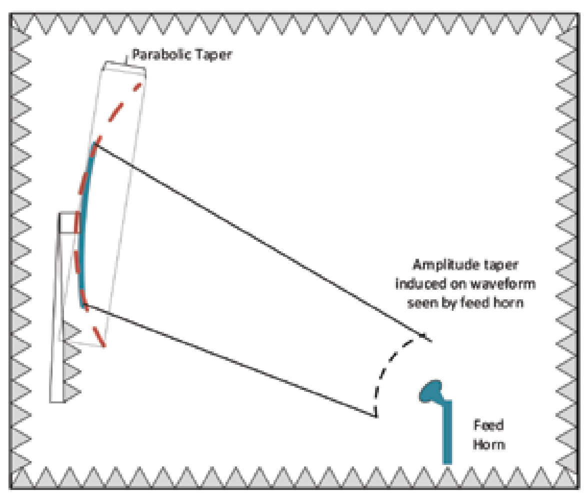
5. Know the Different Ways to Specify Measurement Accuracy – and Why They Are Important.

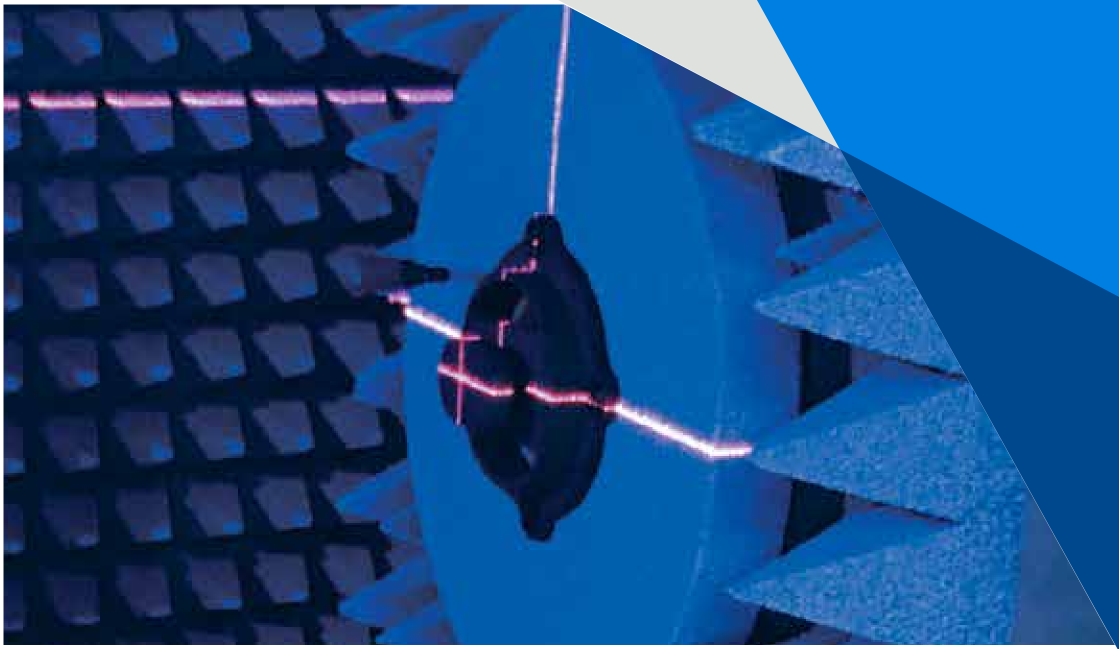
5G FR1 measurement chambers are the familiar fully anechoic rooms from past cellular generations. You are likely acquainted with the ways to specify accuracy in OTA chambers, primarily amplitude ripple within the quiet-zone sphere. For FR1 frequency bands, the prime source of amplitude ripple is a bounced signal that was not completely attenuated by the RF absorber and from the positioner holding the DUT. The constructive and destructive interference of the signal reflections causes amplitude variations across the sphere marking the quiet zone. Longer RF absorbers better attenuate the reflections, but also increase the volume of the chamber necessary to hold them. Specifying a maximum amplitude ripple gives chamber designers the necessary limits to balance size and absorber performance. Often, this maximum is found in the ruling standard or specification, CTIA Certification or 3GPP being the two most common.

CATRs have a different specification for quiet-zone performance, as the source of impairments is different from FR1. Recall from Section 3 that CATRs use a parabolic reflector to focus the transmission in order to achieve a plane wave in a much shorter range than would normally be required by the wavelength of the transmission. The desired effect is a plane wave across the full quiet-zone sphere, as would be achieved in a direct far-field chamber. But there are limitations on the shape of the reflector and what can be attained in so compact a space. The test setups below show the ideal case on the left, where a transmission from the test antenna (in this case an FR2 uplink transmission from a smart phone) is focused by the reflector to form a perfectly planar waveform for a total radiated power (TRP) measurement at the feed horn. For a total isotropic sensitivity (TIS) test, a downlink signal is transmitted by the feed horn and focused to a perfectly planar waveform at the quiet zone and received by the device. In reality, there are limits on how well waveforms are changed or focused by the reflector (shown on bottom right). We can derive some new figures of merit describing the quality of the quiet zone from measuring this impact. Using the parabolic reflector creates a parabolic response in amplitude and phase, specified as a taper across the quiet-zone volume.

FR2 measurement accuracy is also driven by DUT positioning accuracy. Signals at 28 GHz and 39 GHz are highly directional and devices use active antenna systems to point the beam. Finding the beam peak can take sub-degree precision and a significant investment in measurement points to properly characterize the antenna performance.







6. Understand MIMO Measurements for 5G.

Unlike LTE MIMO, which took almost ten years for CTIA Certification and 3GPP to agree upon and publish the necessary corresponding guidance, 5G MIMO tests are defined well enough to plan around now. This definition indicates that over-the-air MIMO tests will be needed for 5G devices, and that useful measurement data can be obtained. Beam steering is such a cornerstone technology of 5G that measuring proper user equipment response to the multipath environment is really no longer an option. User expectations have been set by the extensive marketing of 5G; users won't be forgiving of devices that fail to perform well.

3GPP FR1 MIMO tests will utilize anechoic chambers with 16 dual polarized MIMO probes evenly spaced around the test zone. Several channel fading models are proposed for the RF signals sent to each probe antenna to simulate the multipath that devices experience in actual use. CTIA Certification may utilize an eight-probe ring or follow 3GPP with 16 probes; the decision continues to be under consideration at the time of publication. If your lab is building new MIMO capability, you should consider 16 probes to cover both 3GPP and CTIA Certification requirements.

FR2 MIMO is new territory for CTIA Certification and 3GPP so defining FR1 was an obvious first step. In parallel, FR2 study groups were launched to define work items and explore what sorts of tests would yield useful data. While this work is ongoing, preliminary documents speak to a multi-probe direct far-field anechoic environment with the probes grouped in a cluster rather than evenly spaced in a ring around the device. Single-cluster and multi-cluster tests are being studied. For planning purposes, this specialized chamber will be separate from all others and have a rather small footprint. The current design of some chamber manufacturers will occupy less than 2.3 sq m (25 sq ft) of floor space. Multipath channel fading at FR2 frequencies is not currently feasible, so most systems will use an intermediate frequency, apply the channel model, then upconvert to FR2 channel frequencies.

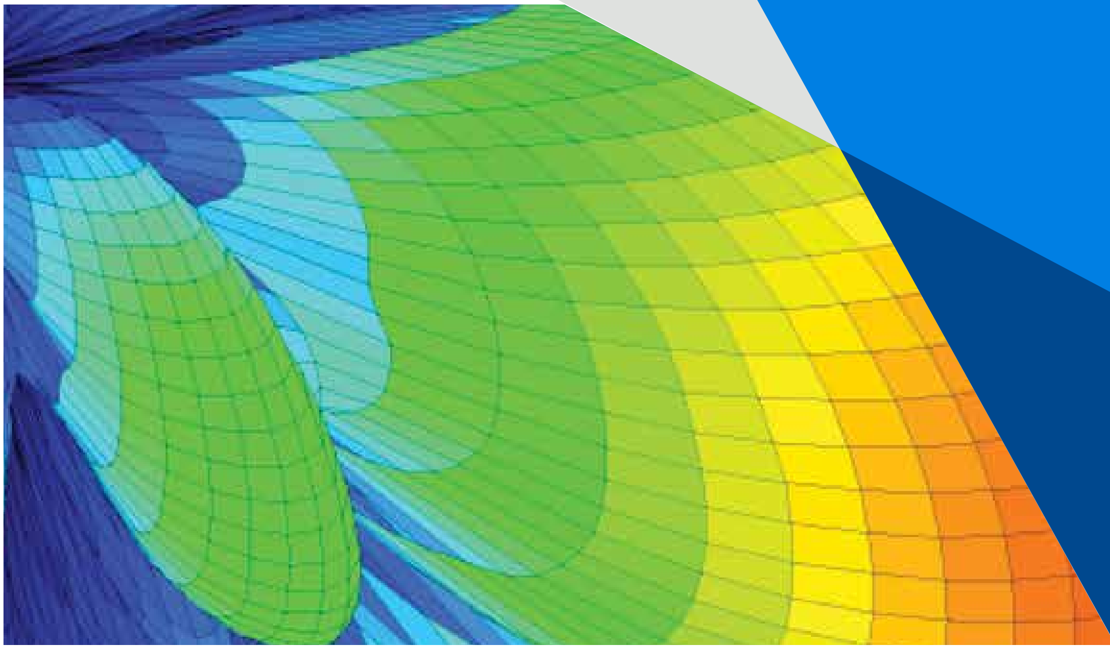
7. Is Your Supplier Up to Date on Global Industry Standards Activity Related to 5G?

Since wireless technology is developing and changing rapidly, in many cases outpacing industry standards, working with a company that actively participates in standards committees protects your investment by guaranteeing access to the latest information when selecting a test solution.

Technical contributors to industry standards are aware of current requirements as well as proposed changes to existing standards. Your supplier's participation assures industry involvement and preparedness not only to anticipate important changes to a standard, but to develop new products and solutions compliant with the latest and emerging standards.

Remember: Your wireless test chamber is a significant investment. To achieve the highest return on this investment, ensure your supplier is active on the wireless industry standards committees, such as the those that issue the standards addressing OTA, MIMO, 5G, and related wireless technologies. These industry standards organizations include IEEE, CTIA Certification, 3GPP, ASC C63®, Wi-Fi Alliance, and others. The ANSI C63 wireless standards are specified by the FCC for wireless devices sold within the United States; ISED Canada has adopted these standards as well.

Ask questions about future performance requirements in the next edition of a wireless standard and whether your test chamber will be able to perform the resulting anticipated tests. In some cases, it may be possible to update a chamber to enhance the performance in order to meet the future standard. Check into these options and have this dialogue with your supplier. Again, this helps protect your investment, so your test chamber is not obsolete when a new standard is published.



8. Appreciate the Options Available in Antenna Measurement Software and How They Impact Your Productivity and Bottom Line.

The software portion of a 5G OTA test system is easily overlooked. After all, the best software is one you hardly notice. Users expect testing without drama or complications. However, 5G is a new radio technology being applied to new use cases and tested by a new generation of instrumentation. The current testing stage is often referred to as “everything is beta,” since the DUT is using a new generation chipset running early firmware. 5G network emulators are also using new hardware running firmware that changes weekly. The software driving the test system may be familiar, but the instrument drivers are constantly being updated as instrument vendors roll out new test features and command improvements. It is important to note that failure to complete the test could be a fault in any direction: device, instrumentation, or OTA system.

Software flexibility is critically important in early technology revisions; it is premature to recognize the best-in-class instrument solution or test approach in the 5G rollout. While instrument vendor OTA software locks you into using only their brand instrumentation, being instrument-agnostic gives back the flexibility to mix and match brands. Rarely do OTA software providers make drivers for different brand instrumentation, especially for wireless network emulators. But mixing of instrument brands is common in most labs, based on what is available, calibrated, and capable on the day of the test. The flexibility to move between chamber and instrument vendors also keeps the focus on becoming the best-in-class and serving the wants and needs of the software users. Competition is good, enabling lab managers with instrumentation-agnostic software to avoid the unenviable position of shutting down 5G tests because a hardware failure occurred or an instrument is out for calibration.

9. Don't Overlook Ongoing Maintenance, Software, and Chamber Support – Confirm What is Available to Protect Your Chamber Purchase.

Once the chamber arrives on-site, consider the next step. Since a wireless test chamber is an expensive addition to your lab, you'll want to efficiently start using the chamber when it is delivered. Ask your supplier what services they provide to support the test chamber system. For example, can they offer an on-site training demonstrating how to use the chamber and familiarizing the staff with the antenna measurement system software? How is the integration of the chamber handled with your existing on-site instrumentation? If you plan to have your chamber industry-certified, does the supplier offer assistance with the CTIA Certification and/or other wireless industry association submittal process? Should you contemplate a maintenance service plan to ensure there's no "downtime" in your lab?

Integration services are often provided for the test chamber with your instrumentation, including a live demonstration of the positioner and the application under test mounting. Yearly verification of system performance may be documented by conducting range calibration, quiet-zone ripple, or other quiet-zone test to confirm quality

Measurement software automates complex tasks and greatly shortens test time, but only if the users are well trained on its functionality. Nothing substitutes for hands-on operational instruction for a new system covering topics like system configuration, installed options, analysis outputs, and maintenance. Periodic refresher training or advanced user training is an important way to keep the lab at peak efficiency.

Regarding an audit of your test lab, can the supplier provide assistance with a CTIA Certification or other industry association lab audit? Confirm whether your chamber supplier can provide education to the required skill levels for an audit. Your chamber supplier should be able to assist with an audit of your lab's customer documentation, assess and develop the measurement uncertainty report of your test lab, perform a pre-audit to assess your lab's readiness, and provide assistance during and after the formal audit.

A maintenance plan should be considered to reduce the possibility of downtime in a chamber. Downtime can adversely delay R&D efforts or invoicing customers for testing services. Ask your chamber supplier what maintenance they recommend and at what frequency it should be performed to ensure the chamber remains fully operational.

It is a good idea to plan these maintenance, software, and chamber support services in advance so they are part of the chamber purchase. To get started, ask to see a training package proposal covering a test chamber similar to your planned chamber that outlines specifically what is and is not included. Then discuss the level of training and support you anticipate needing specifically for your personnel. Confirming your test chamber and software support services in advance allows your supplier time to prepare the instruction and integration materials while coordinating personnel scheduling. Planning ahead ensures your team is educated and ready to start testing efficiently once your chamber arrives on-site and directly contributes to achieving an immediate return on your investment.

10. Consider the Future: Emerging Markets for 5G Base Station and Phased Array Testing.

LTE and 5G have, up to now, focused solely on the user equipment side, primarily on enhanced mobile broadband (eMBB) smart phones. There is a huge shift currently taking place on the carrier side that could bring base station OTA tests to your lab. 3G and 4G base stations were manufactured by a handful of vendors, all with proprietary closed systems from the radio head to the network core. 5G has given the industry a chance to reconsider the proprietary system approach; carriers are now pushing toward a published interface and common radio access networks, so-called open RAN or ORan. ORan brings back the flexibility of using several equipment vendors when building the network, restoring healthy competition and offering a much lower barrier for new companies to enter the space.

New base station vendors will likely outsource conformance and performance tests, both of which must be OTA since active antenna systems are nearly universal. Unlike with user equipment, transmit power and system noise floor are not the primary concerns for base station OTA test systems. Instead, labs can utilize larger direct far-field chambers for FR1 and FR2 base station testing. Fully anechoic rooms are favored and easily accomplished by using removable floor absorber in a semi-anechoic chamber. Even the spectrum analyzer or measurement receiver for EMC could be reused for base station testing, thus tapping into this new market with a far lower initial investment than was made for supporting user equipment tests. 5G base stations will come in many sizes and power classes, and many radio conformance tests are done at full transmit power, so adjustment to the range length between transmitter and measurement antenna is needed to avoid overloading the measurement system. Beam steering antenna arrays that demand several newly published test cases in the OTA environment will also evolve. Optimizing all the system parameters for a successful base station test will require up-front analysis and deeper knowledge of the unit's capabilities than the black-box approach used for handset testing. However, it is anticipated that the lower initial investment and facility reuse will make this an attractive new market your lab may want to address.

Active antenna system research and development is another growing wireless market. Active antenna systems are built with phased arrays that shape and direct or steer the transmission beam. Phased array antennas have been used in military and satellite applications for decades, but now commercial and consumer applications are picking up the technology. The battery of tests to optimize and perfect active antenna systems is quite extensive, so software automation and analysis will cut test time and keep projects flowing. The current trend towards commercializing this technology leads to larger volume manufacturing and lower price points that make them feasible for a growing number of applications. Driving down the cost of the arrays also fosters consideration of new approaches for making these measurements, such as near-field to far-field conversion techniques. Simulation and modeling are advancing, but OTA tests still provide the bulk of the data necessary to commercialize the array. Some chamber manufacturers have embraced this challenging field and introduced innovative ways to characterize the phased arrays. Key technologies such as highly accurate antenna positioners, advanced software, and new chamber designs are available to address this specialized market. Make sure to ask your chamber supplier about these measurements.

Follow these "Top 10 Considerations" to address your wireless test needs now, and in the future! ETS-Lindgren is the partner that consistently delivers the solutions you need. Contact your local ETS-Lindgren representative, phone us at +1.512.531.6400, or visit our website at www.ets-lindgren.com.