OTA testing to gain importance with 5G

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The next few years will see many more wireless users connect to wireless networks. Wireless users will expect a higher level of quality and accessibility from all their devices. Thus, carriers will need to provide better reliability in the network and in devices. The result: Testing will, therefore, need to evolve to more closely emulate actual usage conditions. Over-the-Air (OTA) testing will become essential for engineers to evaluate and certify the reliability and performance characteristics of wireless devices, both for mobile and fixed location.

Testing the components that will support 5G will be vastly different than for 4G/LTE. Connecting mobile devices to test equipment through cables is convenient and cost-effective, but it can't mimic the actual condition these devices encounter. OTA testing lets engineers see what truly happens as the radio waves propagate over the air from the user equipment to the base station and back.

Two main drivers will necessitate OTA testing. The level of integration of the device under test (DUT) will increase significantly, particularly as devices add antenna arrays. Greater integration will make connecting DUTs to test equipment by cables physically impossible. Second, at millimeter wave frequencies, signal absorption rates are much higher, requiring the need for beam focusing or forming to boost the gain. Test setups are needed for beam characterization and for checking beam acquisition and beam tracking performance. OTA testing will become essential.

The current state of OTA testing
OTA testing of wireless devices is required by numerous regulatory agencies, standards organizations, industrial bodies, and carriers. To attain global access and interoperability of mobile systems, certification tests have been developed so that manufacturers around the world provide the same level of quality in all new mobile devices.

Cellular Telephone Industries Association (CTIA) has set standards for OTA testing of 3G and 4G/LTE devices, and has certification labs all around the world. Minimum performance requirements for OTA behavior have been defined in terms of transmitter power levels and receiver sensitivity levels. In the US, wireless carriers have also established industry performance requirements that a device must meet before it will run on a network.

OTA testing is typically used during the R&D phase for all equipment that radiates electromagnetic waves. In current mobile phones, for example, testing is designed to ensure that the signal is homogeneous, in that the same signal is transmitted or received from all directions (Figure 1). It is important that the antenna radiates in all directions, so that the mobile device user does not need to face in a particular direction to get a good signal, nor should a call be dropped as the user passes by a tall building.
OTA testing at cm and mm wave frequencies
For the wireless industry to attain space for these additional users and the wider bandwidth and higher data rates they require, mobile operators need access to higher frequencies. In going to frequencies of 30, 40, 50, 60, and even 90 GHz, the devices enter the cmWave and mmWave ranges. As the wavelength becomes shorter, the transmission distance for a given power level also shrinks. 5G technology must compensate for losses such as free space path loss, atmospheric absorption, scattering due to rain and gases, and line-of-sight issues. The new devices for these applications will become so highly integrated that using cable connections for testing will be very difficult, if not physically impossible, making OTA testing critically important for 5G.

Based on the above losses, the signal absorption becomes much higher at higher frequencies. To achieve the necessary communication distance, providers either need to increase the transmitter power or focus the radiated energy from the mobile device into a sharp, narrow beam (Figure 2).
Figure 2. Mobile devices will need to focus their transmitter beams to maximize transmit power at mmWave frequencies.

Creating narrow beams will require new antenna structures and arrays to ensure proper that beams focusing. There will be a spatial or directional component to the focused beams, which can ensure the beam is pointing in the right direction and switch the beam if there is a blocked communication channel. This beam forming technique will extend the multiple antenna concept known as multiple input multiple output (MIMO) by sending data to different user devices simultaneously. Doing so exploits their uncorrelated locations. Beam forming will also reduce energy consumption; it will target individual user equipment and specifically leave out others with their assigned signal.
Figure 3. Beamforming can direct power where it's needed while minimizing interference to other devices.

Using connectors for testing won't be practical because of their high costs, high losses, and the degree of coupling. Also, in the case of massive MIMO systems, the radio transceivers are integrated directly with the antennas (Figure 4), resulting in a loss of RF test ports, meaning that the DUT radio and antenna performance can only be measured over-the-air.

Figure 4. A 5G capable device could consist of an array of polarized antennas, making wired test ports impractical or impossible.
OTA testing will be a prerequisite for the new designs and their certification. For 5G test systems, the basic components are expected to remain essentially the same, but they must be adapted for the higher frequencies, which will mean smaller antennas.

**OTA measurements**

The key components of an OTA performance test system are the test chamber, the positioning equipment, test instruments for generating and analyzing signals, measurement antennas, and control and report software for automating the measurements. Communication is set up between the device under test and the measurement antennas to make sure the device transmits and receives signals properly. OTA testing is currently performed in a perfect (i.e., shielded and encapsulated) environment, inside an anechoic chamber (Figure 4) which is designed to be non-reflective and echo-free. The size of the chamber varies with the object and frequency ranges being tested, and it is lined with foam pyramids that absorb reflected signals. The testing takes into account radiation characteristics on the equipment while eliminating interference from any other transmissions.
Diverse environments such as using a mobile device indoors or outdoors, in urban or rural settings, in open areas or forests, stationary or moving, or in the presence of other wireless devices are all real-world conditions, can't be quantified for test purposes. We can, however, address real-life through mobile network testing, which is currently also undergoing a transformation for 5G applications. Certification testing is done in specified test chambers that yield accurate, repeatable and reproducible measurements.
OTA testing lets engineers measure performance factors such as signal path, antenna gain and pattern, radiated power, and device sensitivity to both internal components and other devices, as well as reliability and safety issues. CTIA’s Test Plan for Wireless Device Over-the-Air Performance, May 2015, specifies test and setup procedures and measurement methods for power and performance only.

Some of today's key OTA test measurements include total radiated power (TRP) by the device, total isotropic sensitivity (TIS, per CTIA specifications), total radiated sensitivity (TRS, per 3GPP specs), equivalent isotropically radiated power (EIRP), and radiated sensitivity on intermediate channels (RSIC). TRP is an indicator of transmitter performance, while TIS/TRS are indicators of receiver performance. Additional measurements are made to characterize the antenna patterns and efficiency. Co-existence measurements are made to evaluate the degradation in sensitivity that occurs when multiple wireless technologies operate at the same time. OTA testing can be used to improve device performance in areas where problems are identified.

**Challenges in 5G OTA measurements**

There are several challenges related to OTA measurements and setting up an OTA test system. One set of challenges deals with the antenna system. As the technology advances toward 5G systems, finding the proper setup and positioning for the 3-D antennas to test the moving beams, while accounting for interference and scattering, will be difficult. A new measurement dimension—space, or power versus direction of departure—must be included.

One particular factor that the devices must account for is the blocking effect of the human body on the radiation pattern, through using phantoms during OTA tests, as shown in Fig. 5. OTA tests measuring the three-dimensional antenna pattern can be performed in either near field or far field (Figure 6). Measurements in near field allow smaller anechoic chambers for the measurement, but require setups capable of measuring both phase and amplitude with high location precision and additional post processing for the near-field to far-field transformation.

![Figure 6](image1.png)

Figure 6. Near-field and far-field OTA measurements require different test setups.
A second challenge is that each individual transceiver in the active antenna system needs to be characterized through an OTA interface, with measurements made for both the transmitter and the receiver. Each transceiver must turn on for individual verification or a set of transceivers must turn on for joint assessment.

A third challenge relates specifically to beam forming. Due to the high path loss and limited range of a mmWave wireless system, precise beam generation and thus tracking and fast acquisition is required for mobile users. Whereas with antenna implementations for existing cellular technologies static pattern characterization was sufficient, mmWave systems will require dynamic beam measurements to accurately characterize beam tracking and beam steering algorithms.

Other challenges relate to testing the devices for RF conformance, which today relies on well characterized cabled test-port connections to allow for repeatable measurements. Such a test setup and the necessary calibration needs to be defined in an OTA environment because 5G RF devices will lack test ports accessible through connectors.

Production test brings on even more challenges. Radiated device tests must be performed for every wireless-enabled device. Given how rapidly devices are produced, OTA test systems will need to be flexible and quickly adapt to meet the testing needs of future and unforeseen devices, without sacrificing any quality or depth in the testing methods. Engineers will need to Calibrate the antenna system to ensure that the misalignment between RF signal paths is below a specified limit, and functional tests of the completely assembled unit must all be performed.

**Conclusion**

5G technology presents new challenges for OTA testing, in that new testing methods and equipment will be needed for mobile device designs that have not yet been finalized.

As 5G wireless evolves, the role of OTA testing will become more critical. With higher levels of integration and mmWave frequencies, conducted measurements using test ports won't always be possible. Device designers and manufacturers will need to rely on OTA testing to validate device performance. In addition, as 5G device designs are finalized, OTA test system suppliers will need to work closely with RF/wireless engineers develop new test methods.

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