Proving 5G:

How OTA Testing Helps Enable a New Mobile Era

It may have been many years in the making, but the mobile industry finally has reached the dawn of the 5G era. Across the sector, mobile network operators are preparing their initial 5G launches, planning their migrations from field trials to commercial offerings.

Across the globe carriers made news with such launches as 2018 ended. In the U.S., for example, both Verizon and AT&T announced 5G-based services in some markets. In Korea, the government is requiring the three national operators – KT, LGU+ and SKT – to start offering mobile 5G services in early 2019. The activity will ramp up in 2019, with spectrum auctions completed in many countries and ongoing in the U.S. along with frequency band allocation processes throughout the world providing carriers with the additional spectrum many of them will need for 5G.

For example, the Federal Communications Commission's (FCC) 24 GHz and 28 GHz spectrum auctions have concluded, with the latter raising more than $700 million from a variety of network operators beginning the migration to 5G. The FCC plans to begin auctioning off spectrum for 5G in other millimeter-wave (mmWave) bands — 37 GHz, 39 GHz and 47 GHz — in the second half of this year. In many countries carriers plan to refarm existing spectrum below 3 GHz currently allocated to LTE services and globally, the spectrum around 3.5 GHz is being allocated for 5G networks.

The additional spectrum they are gaining through allocation processes, which in some cases will be as much as 100 MHz in the sub 6 GHz bands and up to 800 MHz in the millimeter-wave bands, will allow operators to deploy networks capable of much more than current networks. This includes higher bandwidth and much greater data rates for customers, as well as extremely low latency

Image 1. This bank of antennas on the side of a sports stadium includes a 5G NR radio (third from left). LTE and WCDMA antennas are co-located, with LTE providing the non-stand alone (NSA) signaling during the early phases of 5G network roll out. With multiple transmitters co-located, care must be taken with OTA measurements to not over drive the input stages of the test equipment.

to support autonomous driving, mission-critical applications with real-time response needs, and the coming explosion in Internet of Things connections to create smart homes, smart buildings, smart factories and smart cities.

Enabling these visions requires a great deal of investment by network operators, not only in the millions of dollars they bid to acquire new spectrum, but also in terms of building out a whole new wireless architecture that is much denser and capable of greater coverage and richer application experiences than ever before. Initially, network operators will leverage existing 4G infrastructure to help them launch 5G, this is the so called non-standalone (NSA) network architecture where signaling is performed over the legacy LTE network. Over the long term, mobile carriers will build out new 5G networks using their higher-frequency spectrum allocations, deploying entirely new antenna technologies in the process.

The nature of those higher frequencies requires new thinking about how to build networks, according to Angus Robinson, product marketing manager at Anritsu. "Because the most common spectrum allocations for 5G services are at around 3.5 GHz or in the 28 GHz and 39 GHz mmWave bands, the signal doesn't travel as far, just because of the laws of physics," he said.

That means one of the big differences between 4G and 5G, architecturally speaking, is that while 4G networks used base stations that held omni-directional antennas transmitting ubiquitous signals, 5G will use base stations with active antenna systems (AAS) with beamforming and massive MIMO to help focus strong signals toward each device in the coverage area.

A base station with massive MIMO and beamforming, according to the IEEE Spectrum video "5G Technologies: Beamforming Explained," acts like a traffic signal in the network, keeping track of the timing and direction of arrival of all the signals in its coverage area, and use signal processing algorithms to plot the best route for a

Image 2. Multiple elements in a 5G NR active antenna system each have their own RF amplification and antenna components. When making OTA measurements, it is best practice to have the instrument antenna in the far field.

signal to get to each device in the coverage range, potentially even using building reflections to establish the best path.

Such approaches already are being used in wireless networks, especially in situations where network operators need to handle event-oriented traffic spikes in certain portions of their networks. For example, at the 2018 FIFA World Cup tournament, Russian service provider MTS used Ericsson equipment with 5G plug-ins supporting massive MIMO to support high-quality, high-reliability mobile Internet experiences for World Cup attendees.

5G networks will be more densely packed with many different types of transmission sites - not just macrocells, but an abundance of mmWave small cells providing massive data capacity in small geographic areas. The new antenna systems feature transmitters the size of carry-on bags holding typically 64 or 128 antenna elements, with RF circuitry connected to each antenna, Robinson said.

"Antennas have changed from traditional cell site directional antennas transmitting a downlink signal to a wide geographic area to those that use beamforming technology so that the power can be focused into a beam rather than transmitting it ubiquitously, as with LTE," he said. "The antenna typically has 64 elements in it, and by changing the phase of transmission in each one of those elements, you can focus a beam and transmit energy specifically toward the mobile user or other device that is connected to the base station."

As beams are transmitted with narrow beamwidths, there are radiated power characteristics that need to be kept at a minimum to avoid interference. These include side lobes, which form adjacent to or behind the main signal beam, and can contain considerable power with the potential to interfere with other signals. Generally, the decibel level is much lower than in the main beam, but in a dense network, side lobe level still needs to be monitored and managed.

Such architectures, while complex, will allow operators and their customers to maximize the potential of 5G. However, to get customers to buy into this vision, operators and manufacturers need to prove 5G is everything they claim it is. Just as 5G at high frequencies requires new thinking about antenna architectures, it also requires new thinking about testing these networks to make certain that all the technical characteristics can be effectively managed to prepare networks for launch.

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THE EVOLUTION OF SPECTRUM ANALYZERS

As 5G deployments are now becoming a reality, RF technologies are reaching into ever more areas of our lives and the RF spectrum at all frequencies is becoming more crowded. In addition to the spectrum demands of cellular systems at sub 6 GHz, 5G radios are now being deployed in the millimeter-wave (mmWave) bands above 32 GHz to support the fastest speeds. The ability to view the RF spectrum continuously — from as low as 9 kHz and into the mmWave bands beyond 24 GHz — as well as measure the transmissions from all of these systems is increasingly important to avoid interference and guarantee performance. It's imperative that the next-generation of test equipment be designed to meet the challenges of 5G test while maintaining support for a full range of other wireless technologies in use today.

HIGH-PERFORMANCE CAPABILITIES AND SUPPORT FOR CRITICAL APPLICATIONS

These next-generation test instruments must deliver the highest levels of performance while providing field engineers and technicians unparalleled measurement accuracy. These new solutions must provide continuous frequency coverage sub-3 GHz, sub-6 GHz, and mmWave 5G NR measurements. They must be able to support critical functions such as:

- **Interference hunting and spectrum clearing networks –** fast sweep speeds and low distortion front-end are critical to help deploy new networks efficiently, ensuring spectrums are clear and validating that all legacy users have stopped all transmission.

- **Broadcast transmitter analysis –** deliver a comprehensive range of transmitter measurements — including: harmonic, spurious, occupied bandwidth, channel power, and adjacent channel power – to ensure conformity to regulatory requirements

- **Microwave radio links –** offer continuous coverage beyond 24 GHz, power and modulation bandwidth can be verified during installation or maintenance testing

- **Satellite system monitoring –** ideal for monitoring downlink signals to search for interference and noise

- **5G NR base station measurement –** validate the performance of the gNB base station with essential measurements that are in full compliance with 3GPP TS 38.104 V15, such as: frequency error, time offset, cell/sector ID, modulation quality, unwanted emissions, occupied bandwidth, adjacent channel leakage ration, transmitter spurious to 12/75 GHz, EIRP, and synchronization signal block (SSB)

- **5G coverage mapping –** monitor signal strength of 5G transmitters over intended geographic area by continuously measuring RF data – including 5G channel power, EIRP, or RSRP

THE NEXT-GENERATION OF HIGH-PERFORMANCE SPECTRUM ANALYSIS

With the launch of Anritsu's Field Master Pro™ MS2090A high-performance RF spectrum analyzer, the world's first field portable solution with continuous frequency coverage for sub-3 GHz, sub-6 GHz, and mmWave 5G NR measurements has been introduced. This instrument was developed in close cooperation with all leading 5G base station manufacturers, and is being used to install the first commercial 5G NR networks. The new Field Master Pro MS2090A high-performance spectrum analyzer is the most comprehensive solution for field service engineers and technicians supporting the installation, commissioning, and maintenance of the RF industry's wireless technologies of today and tomorrow.

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THE FUTURE OF TESTING: OVER THE AIR

Testing 5G networks will not be the same as testing 4G architectures, or really any type of wireless network that came before. Traditionally, to test and prove base stations and antennas were working properly, transmitting the expected strength of signal, network technicians used test instruments that they physically connected to the base station via a coaxial cable to an RF test connector. Doing so allowed the test instrument to make calibrated measurements for channel power and modulation quality, as well as decoding some basic cell site information. The design of an LTE macro site usually comprised of a radio base station in an equipment room at ground level, with long RF cables feeding the antenna high up on a tower. These cables regularly had lengths of over 10 meters, and the losses and reflections in this cable feed to the antenna was a common source of performance issues that needed testing.

This type of testing is no longer practical for multiple reasons. Robinson explained that base stations have evolved to be split into a baseband unit (BBU) with a remote radio head (RRH) and a fiber cable linking the two. More equipment also got moved to rooftops and other hard-to-reach places, which did away with testing by coaxial cable. Finally, base stations and antennas have been more densely packed within closer distances to one another to enable powerful individual beams to be steered to each user.

That means "base stations" no longer exist in the traditional sense of that phrase. The RRH does not have a test port because it does not have a single RF output to a common antenna. It has an antenna array with typically 64 elements. So no single RF test port can monitor all the antenna elements. Testing needs to be performed on the beam formed by the AAS over the air. This beam is only fully formed at some distance from the AAS, which for the 3.5 GHz radios is usually at least 10 meters away. If the AAS is mounted on a rooftop, the tests must be done much further away than that.

Image 3. A typical 5G NR 3.5 GHz rooftop installation. The location by the edge of the building roof prohibits OTA measurements on the rooftop. OTA measurements need to be made at ground level in the far field. Inputs to the 5G NR AAS are power and data (over fiber).

"Ideally, you don't want you're technician hanging off the side of a building trying to test an antenna if it's on the corner of a rooftop, so in some cases you might be 100 meters or so away down on the ground," Robinson said.

These new realities have given rise to over the air (OTA) testing, allowing technicians to position themselves in the far field distance from a base station, and wirelessly connect to carry out new types of tests that make more sense in environment where operators need to validate the performance of many individual beams.

The new tests include measuring Equivalent Isotropic Radiated Power (EIRP), a measurement indicating the amount of power that would be required to be fed into an omni-directional antenna to give the same signal strength as that measured at a distance and direction from the antenna. Robinson explained, "With a traditional antenna, you're transmitting power in all directions. Because we're talking about beams of power now, people want to know what would be the equivalent power in an omni-directional antenna"

He added, "EIRP shows the effectiveness of beamforming technology. It says to achieve the power I'm measuring at this active antenna, an omni-directional antenna would have had to be transmitting kilowatts of power." Essentially, knowing the EIRP measurement helps manufacturers validate that their transmitters are performing as promised.

Russel Lindsay, product manager at Anritsu, said OTA testing also can take other measurements that make it the best possible testing method for 5G. For example, with 5G's wider-band signals, companies will want to test for interference where signals may overlap.

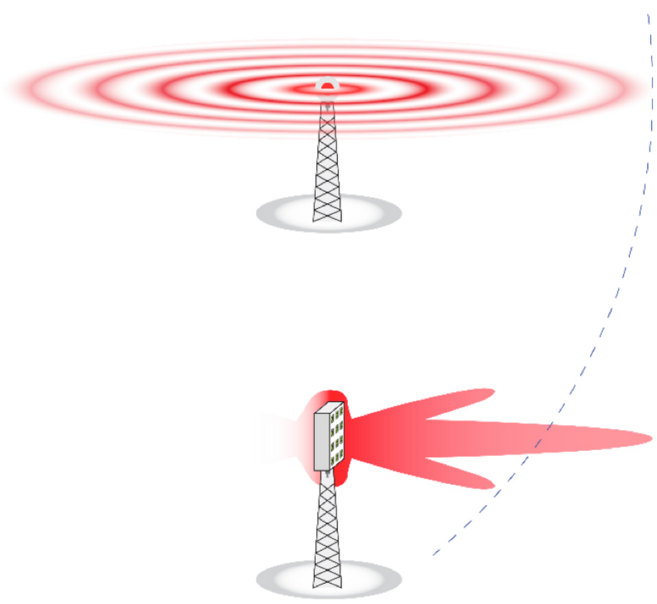

Image 5. For 5G gNB measurements, EIRP becomes an important measurement as the power is now focused into beams, meaning the traditional measurement techniques used for omni-directional or sectorized antennas no longer provide a clear understanding of the effective power from the transmitter.

"These are wider band signals than the industry is used to, so now you're going to want to test the boundaries of these signals, how much someone else's signals may be bleeding into your bands, and how much your signal is bleeding into their bands," Lindsay said.

In addition to spurious and harmonic signals, beamformed signals can generate side lobes that could be radiated in any direction from a base station during transmission, and OTA testers can measure these signals. "Harmonic and spurious testing will be a big deal because when you introduce high-powered signals, you want to be sure that whatever else is generated is below a strength level where they would cause interference," Lindsay said

Other OTA measurements include testing the power in each of the primary synchronization signals in the 5G sync signal block. The beams in the SSB are continuously transmitted and so offer a useful signal to perform basic RF measurements on in the field. Measurements on data channels will always be more challenging, as these beams are only formed after a UE has established a data channel with the base station, and these beams will be directed to the UE. So without some signaling or UE capability in the test instruments, creating and aligning with these beams will not be possible.

In the future, because OTA unchains technicians for the old methods of testing via a cable connection, companies could develop some innovative methods for administering tests. For example, Lindsay said conducting OTA tests remotely via flying drone could be a future possibility, as drones might be able to take measurement in far field locations that are inaccessible to human technicians on foot. We have already seen a number of prototype drone-based solutions for 5G AAS testing, said Lindsay.

Ultimately, using OTA testing systems for all of these needs will help network operators and their manufacturer partners prove that new 5G networks are ready to perform as anticipated. That means they can meet their time-to-market goals for 5G, opening the door to new applications and user experiences that will change the lives of consumers, and usher in a new era of productivity and performance for individual corporate enterprises and entire industries.

"If you make a measurement over the air, you are making a measurement that you otherwise never would have been able to make at all," Robinson said. "OTA testing is most closely aligned with the real-world experience of network users. It is the most meaningful way of making measurements on a 5G transmitter."

Image 5. Cut out highlights location of two 3.5 GHz 5G NR AAS. Again the inputs are data over fiber and power. All RF measurements at this location were made OTA during the installation process.