Boost Performance and Reduce Risks in Military-Grade 5G

KEYSIGHT

BROCHURE

Table of Contents

Cover image: U.S. Navy photo by Mass Communication Specialist 3rd Class Carter Radke

Step Up from Commercial 5G Networks

The primary use case for 5G stems from consumer demand for multimedia entertainment that fits on smaller screens and delivers an immersive user experience. Infrastructure and service providers are responding with more bandwidth on two fronts: squeezing more bits into the existing cellular spectrum and opening new spectrum at higher frequencies for next-generation mobile devices.

Much of the technology inside 5G — like high-frequency RF design and complex digital modulation — came from previous innovations in defense and aerospace applications. Following in the spirit of commercial-off-the-shelf initiatives, 5G technology will find broader use in defense and aerospace circles, offering transformative user experiences.

Bandwidth also transforms devices. 5G powers smartphones and tablets and provides enough bandwidth for high-speed internet through a 5G-enabled Wi-Fi hub. Vehicle-to-everything (V2X) concepts connect 5G-enabled cars and trucks to data and sensor networks, paving the way for vehicles to communicate directly and enhance safety. Robots and drones also connect over 5G, accepting commands and streaming real-time video. Cellular Internet of Things (IoT) technology, co-existing with 5G coverage in dedicated subbands on the same towers, opens possibilities for swarms of new connected devices, providing more information about monitored equipment and surroundings.

U.S. Navy photo by Mass Communication Specialist 2nd Class Caylen McCutcheon

Enhanced 5G usability and bandwidth translate directly to use cases for military personnel, first responders, and agency employees. The term military grade implies physical requirements like extended operating temperature, shock, vibration, and salt spray resistance. In practice, it means much more. Military-grade 5G network designs must deal with these basic requirements and demands on hardware and software from higher levels.

Advanced requirements, such as 5G non-terrestrial networks (NTNs), will reshape future military-grade deployments. NTNs will likely change the conventional view of satellite design, moving away from static 20-tonners toward larger constellations of smaller platforms constantly in motion. How NTNs organize, including how software partitions across platforms and how they connect, is a new frontier. Latency and Doppler pre-compensation become significant concerns.

Keysight focuses on 5G terrestrial and non-terrestrial challenges where test and simulation solutions are crucial in deploying military-grade 5G networks in less time, with higher performance, improved network reliability and quality of service (QoS), and lower risk. Keysight solutions serve the 5G ecosystem of component makers, equipment designers, integrators, and service providers.

U.S. Navy photo by Mass Communication Specialist Seaman Sasha Ambrose

At a system level, teams deploying military-grade 5G networks face four overarching challenges beyond the experience of many commercial deployments: rapid deployments, dynamic environments, more and varied devices, and long life cycles. The insight required to deploy, troubleshoot, and optimize network performance and reliability deepens, with lives and property depending on the results. Speed, accuracy, and the ability to share models, data, and analysis are mandatory for any solution. State-of-the-art emulation and simulation solutions, coupled with test and measurement equipment, increase the ability to quickly evaluate and validate networks and devices where physical test setups can be tricky.

Rapid deployments

Commercial 5G system deployments typically have time on their side. Careful planning includes selecting equipment, surveying locations for optimum coverage, constructing base station towers and equipment shelters, and verifying compliance with regulations.

Military-grade 5G networks often deploy in unforeseen locations without much notice and in uncontrolled conditions with little time to get up and running. Equipment must be portable, delivered by helicopter, light vehicle, or, in extreme cases, carry bag. Instead of a large, fixed antenna tower, setups may include vehicle-mounted booms, aerostats, and high-altitude pseudo-satellite (HAPS) platforms like airships, drones, balloons, and low-earth orbit (LEO) satellites. Quickly identifying placement locations and assessing coverage is essential.

Keysight delivers proven measurement science for 5G field testing, providing faster, more accurate results. A deep understanding of authentic RF signals and real-world effects translates into advanced algorithms for complex time and frequency domain measurements in noise. Keysight solutions support all four phases of 5G network evaluation: user equipment (UE) emulation, channel emulation, gNodeB (base station) testing, and core network testing.

Photo by Richard R. Schünemann

Dynamic environments

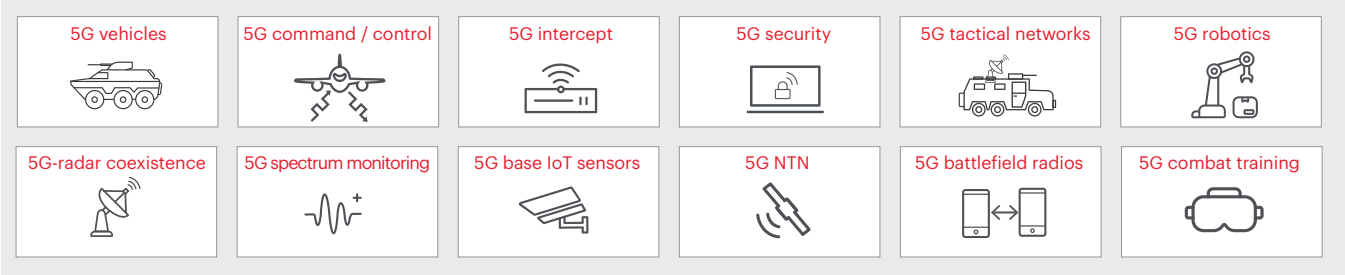
In a disaster response scenario, setting up a military-grade 5G network may be more straightforward as conflicting electronic emitters in the area are often inoperative. But in a military operation, other emitters can be numerous, with radar systems (including nearby commercial radar), tactical radios, satellite communication terminals, electronic warfare gear, directed energy weapons, and more.

Coexistence can be tricky. A 5G network that works perfectly in one location may have severe problems operating in another. Spectrum conflicts may arise when the 5G network and other equipment occupy the same operating frequencies. Or more subtle interference, continuous or intermittent, may throw 5G modulation slightly out of specification with increased bit error rates. Also, 5G operation may affect the performance of other gear.

Keysight RF system simulation solutions help model 5G environments, predicting performance in virtual space before problems appear in physical results. Model-based systems engineering (MBSE) strategies can account for dynamic elements like antenna orientation, nearby emitters, and HAPS and satellite motion, simulating how 5G signals change during operation. Simulation results inform configuration decisions.

Increasing device variety and numbers

Setting up one 5G network in a location and immediately connecting a wide variety of wireless devices and platforms provides immense benefits for warfighters, agencies, and first responders. The scalability of military-grade 5G networks is also a plus, supporting small squads to entire theaters. Defense applications for 5G span sensors, handhelds, vehicles, and satellites.



Keysight test and simulation solutions extend and scale with customer-supplied models and hardware-in-the-loop strategies for testing existing and newly developed devices. UE emulators support thousands of active devices simultaneously. Simulation software scales for more extensive, faster runs on cloud and high-performance computing platforms.

Long life cycles with evolving specifications

Defense users value extended life cycle support for hardware and software. However, 5G technology evolves along a much shorter commercial life cycle, driven by research and frequent specification updates from the 3rd Generation Partnership Project (3GPP), the O-RAN Alliance, and other ecosystem proponents. A good example is 5G NTNs, which have partially defined specifications but still no end-to-end system solutions.

Measurement science must keep pace, protecting investments in high-precision equipment and simulation software without requiring dreaded "forklift upgrades" for all-new solutions. A test and simulation approach defined now must be able to adapt as discoveries occur.

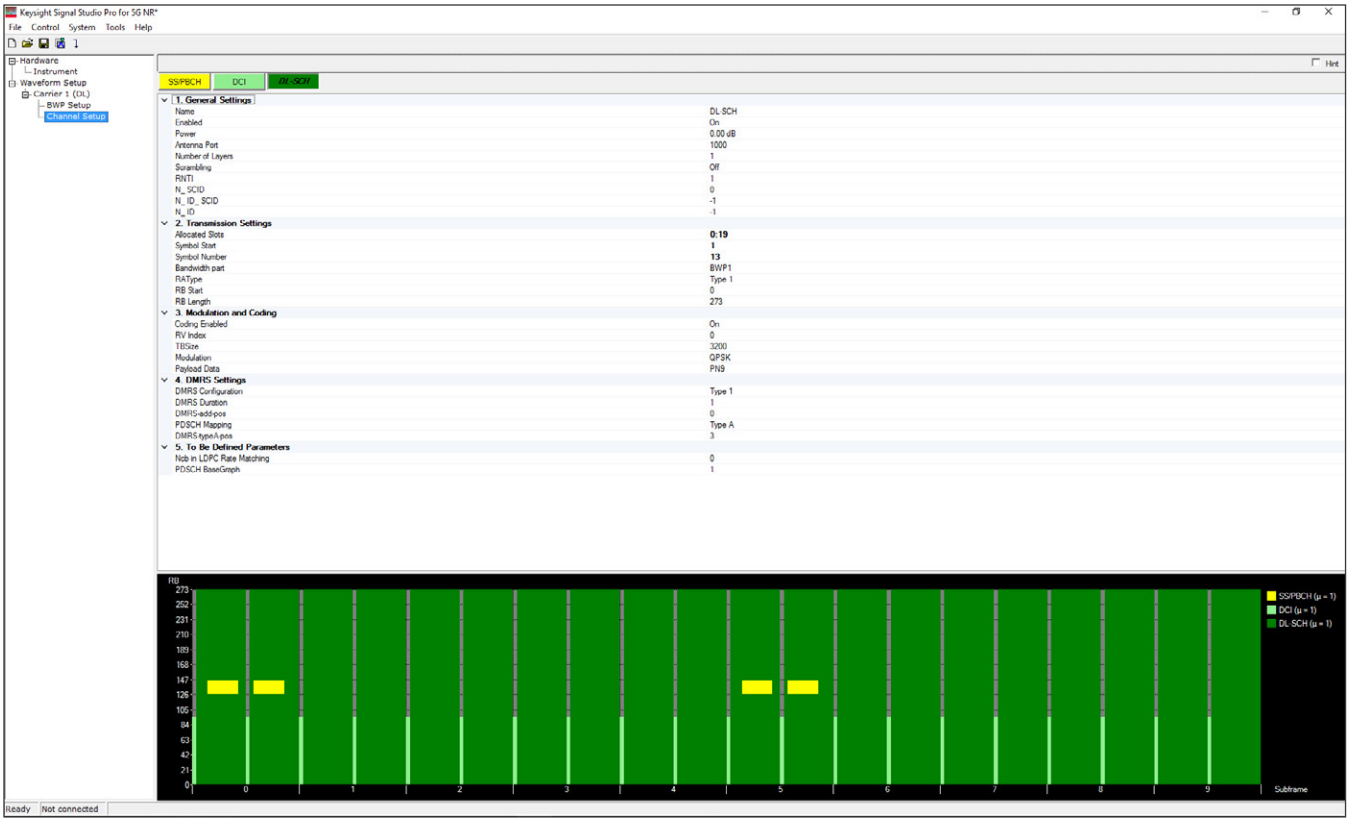
Keysight continuously upgrades its test solutions through major annual releases of new instrument and simulation software packages. Research is already underway on the design and test of 5G-Advanced, 5G NTN, and 6G equipment, embracing the latest features as they progress in working groups. Keysight solutions appear throughout the 5G ecosystem, from RF chipset suppliers to device manufacturers to network integrators.

Simulate Modulation and Effects

A significant change in 5G system design is the observation that it is impossible to evaluate system performance without using authentic, higher-order modulated signals of sufficiently wide bandwidths. 5G features 256-QAM modulation, packing 8 bits into each symbol in a constellation. Error vector magnitude (EVM) emerges as a critical metric for signal quality and transceiver and equipment performance. EVM measures how accurately transmitted symbols match their intended spot in the QAM constellation. Noise, distortion, nonlinearity, loading, channel interference, and other effects lead to points landing off their mark, resulting in discrimination errors.

Solution: Authentic waveforms in virtual and physical space

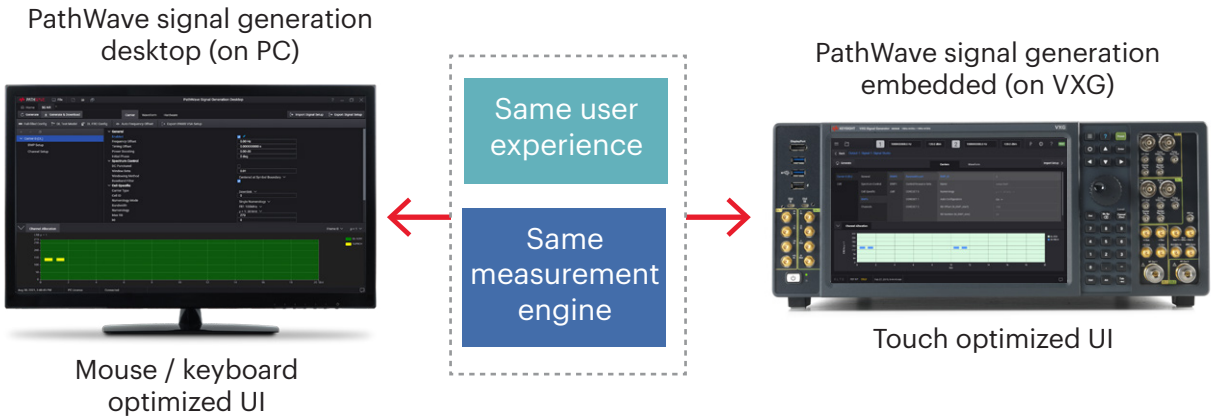
Keysight PathWave Signal Generation, an easy-to-use PC-based software application, dramatically reduces the time spent developing authentic waveforms for many applications, including military-grade 5G. It creates calibrated, performance-optimized reference signals, with or without impairments, conforming to various industry standards. Its user interface features tree-style navigation with graphical, parameterized signal configuration.



The capability of PathWave Signal Generation extends with bundles, including **Keysight N7631C PathWave Signal Generation for 5G NR.** It generates 3GPP specification-compliant 5G New Radio (NR) signals, with frequent updates to keep pace with new specification releases, a direct outgrowth of Keysight's participation in industry standardization efforts. It supports parameters such as variable numerology and subcarrier spacing, downlink and uplink channels, carrier aggregation, channel coding, and multi-antenna configurations. It also supports test model presets for 5G frequency ranges FR1 and FR2 and dynamic spectrum sharing for testing 5G NR coexistence with other emitters.

Added signal authenticity comes with **Keysight N7605C PathWave Signal Generation for Real-Time Fading**. It simulates different propagation environments by applying real-time fading with various models, including Rayleigh, Rician, Suzuki, log normal, pure Doppler, and constant phase. Preconfigured setups aid in conformance tests.

Customizing waveforms for research (such as preliminary 5G-Advanced or 6G concepts) or stress tests beyond specifications is simple. The waveforms PathWave Signal Generation produces have high resolution and wide bandwidth ready for testing EVM, adjacent channel power ratio (ACPR), and other metrics.



The measurement engine in PathWave Signal Generation also drives waveforms in many Keysight vector signal generators. Users can set up signals in the desktop version, use them in simulations, then embed them into various Keysight microwave signal generators for use as physical stimuli. Starting with the same authentic waveform in virtual and physical space is essential for creating simulations matching measurements, a key enabler for military-grade 5G digital twins.

Want to Learn More?

- www.keysight.com/find/signalstudio
- www.keysight.com/find/N7631C
- www.keysight.com/find/N7605C

Solution: Multi-domain simulation for RF system engineering

Another essential feature for complex RF system simulations is models with real-world effects represented. RF propagation and interference change as ground-based platforms move and reorient. An RF system that functions well in one location may display problems when a nearby site introduces emitters. The kinematics of HAPS and LEO platforms may create issues.

Keysight PathWave System Design represents RF systems using high-fidelity RF modeling in Sys-parameters, S- or X-parameters, using prebuilt library blocks or models built from datasheets. Fast circuit envelope techniques speed up simulations without losing accuracy.

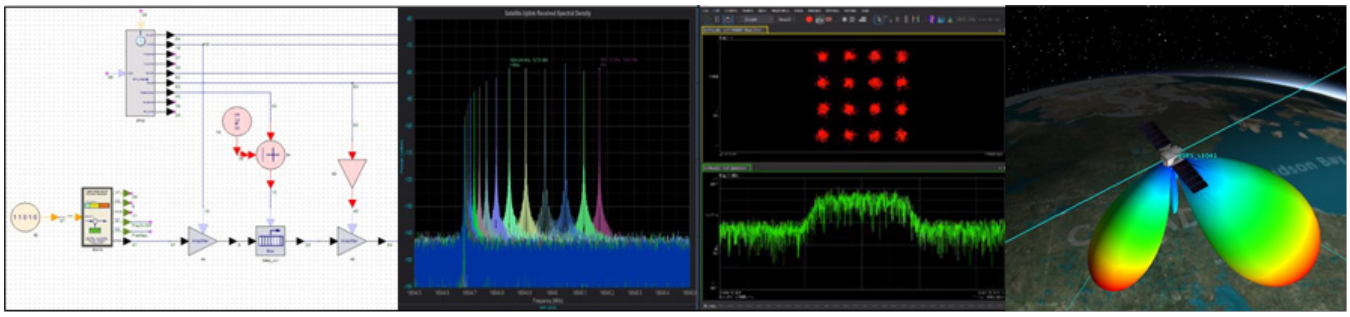
There are three core capabilities:

- Time-domain simulation addresses complex scenarios such as adaptive modulation, system agility, and dynamic resource allocation.
- Frequency-domain simulation analyzes harmonics, intermodulation, frequency planning, layout coupling effects, and parasitic issues.
- Cross-domain simulation captures up- and downconversion, spectral inversion, thermal and phase noise, frequency / power dependence, and more, with RF impairments recognized.

Extended RF system engineering capability comes through direct integration with popular tools.

- **Keysight PathWave EM Design (EMPro)** analyzes 3D electromagnetic (EM) effects of components, enhancing in-context models.
- Digital mission engineers can use ANSYS STK to connect accurate platform motion and antenna orientation models with multi-domain RF simulations.
- EM propagation and channel models created in Wireless InSite can also directly connect with multi-domain RF simulations.

Teams combining authentic waveforms and high-fidelity modeling and simulation realize a major benefit: scenarios too challenging to stage and measure in the physical world are quick to model and evaluate in the virtual world.



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Deploy Military-Grade 5G in Two Scenarios

A government entity can choose a service provider to deploy and manage a 5G network, or it can take a do-it-yourself approach. No matter which it chooses, the network will require testing in at least one of four areas.

Service provider networks

A service provider may contract with government entities to deploy and help manage a 5G network, and a provider may be preferable for permanent installations in noncombat zones. It may also be an option in temporary deployments, particularly a public network where agency and civilian users need coverage, such as in the aftermath of a natural disaster.

The service provider understands the network and its capability and should be able to describe its characteristics in this scenario fully. Still, it falls to the agencies involved to verify network performance and service limits because of specialized devices and network reliability needs.

Self-deployed networks

The other scenario is a self-deployed 5G network. Such networks range from temporary, set up and torn down relatively quickly for a specific operation, to semipermanent deployments in forward areas where 5G network coverage serves tactical and personal communications needs.

Unique network configurations, highly mobile assets, specialized devices, tight security, and mission-critical reliability increase the test and evaluation burden. Agencies must characterize all aspects of network performance and service limits, possibly in hostile conditions.

Four operational domains for 5G network testing

Evaluating either of these deployments means testing in one or more of four operational domains:

- User equipment (UE), more commonly thought of as connected devices.
- gNodeB instances, the 5G terminology for base stations.
- Channels and how signals propagate across spaces and through obstacles.
- The radio access network (RAN) and core network infrastructure behind everything.

Keysight's proven state-of-the-art test and measurement hardware and software for all four domains start with gNodeB emulation solutions.

Test gNodeB Instances

Testing a gNodeB involves three aspects: emulating a gNodeB to test connected devices, examining protocol and physical-layer interaction, and measuring coverage on a deployed gNodeB in the field. Each is critical to understanding how fast and reliable a network is under various conditions.

Solution: gNodeB emulation

Keysight's gNodeB emulator solution has both hardware and software components. First is the **Keysight E7515B UXM wireless test platform**. It emulates a gNodeB and enough core network functionality to form controllable, repeatable UE tests that can be difficult to set up on a physical network. It supports multiple 5G NR and LTE radio access technologies in a single unit, including non-standalone or standalone modes, with scalable bandwidth in the 5G FR1 sub-6 GHz frequency range. It supports metrics like block error rate, sensitivity, throughput, and latency, and advanced features such as baseband fading and multiple angle-of-arrival (AoA) tests.

The E7515B extends into 5G FR2 frequencies with the addition of the **Keysight E7770A common interface unit** and the **Keysight M1740A mmWave transceiver.** Adding up to eight M1740A transceivers facilitates AoA testing in 28, 39, and 40 GHz bands.

Additionally, gNodeB emulation delves into protocols with **Keysight E7515B UXM test platform software**, a companion tool that works with the E7515B UXM wireless test platform. It accelerates the workflow for new devices with protocol stacks for 5G NR, LTE, C-V2X, and more, and enables users to define custom protocols in device and network research. It can also help with cybersecurity tests by injecting messages with altered structures to see how UEs react.

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> www.keysight.com/find/E7515B

Solution: gNodeB protocol analysis

Deeper protocol analysis is often necessary to troubleshoot interactions between UEs and gNodeB instances or debug test case failures. Finding root causes can be a time-intensive process, and looking through log files is inefficient and may miss clues to the problem.

The **Keysight SJ001A WaveJudge wireless analyzer toolset** and the **Keysight WJ5900 WaveJudge 5G real-time wireless analyzer** work together to provide real-time 5G protocol stack decoding and triggering.

WaveJudge Advanced software can analyze complex antenna schemes, compare expected versus received frame structure, identify allocation issues, identify synchronized and reference signal errors, visually inspect schedule performance, trace bytes as they move through protocol layers, and more. Messages correlate to PHY events in views revealing information often not found in equipment logs.

The integrated IntelliJudge feature takes real-time decoding a step further, allowing for event-based, message-based, or error-based triggering in 5G and 4G protocol stacks. Analyzing radio physics-related metrics for anomalies can help isolate problem areas regardless of the layer in which they occur.

The **Keysight S8701A Protocol R&D Toolset** makes developing and executing tests of 5G NR protocols easier. It accelerates test case creation and analysis and enhances logging with advanced features for rapid debugging. Tests can dive into the protocol state machine using dynamic control points, and test engineers can modify parameters conditionally during test execution. Extensive scripting features maximize reusability. An integrated test manager helps automate large test campaigns and parameterize tests. Users can export reports to Excel or HTML.

Want to Learn More?

- www.keysight.com/find/SJ001A
- www.keysight.com/find/S8701A

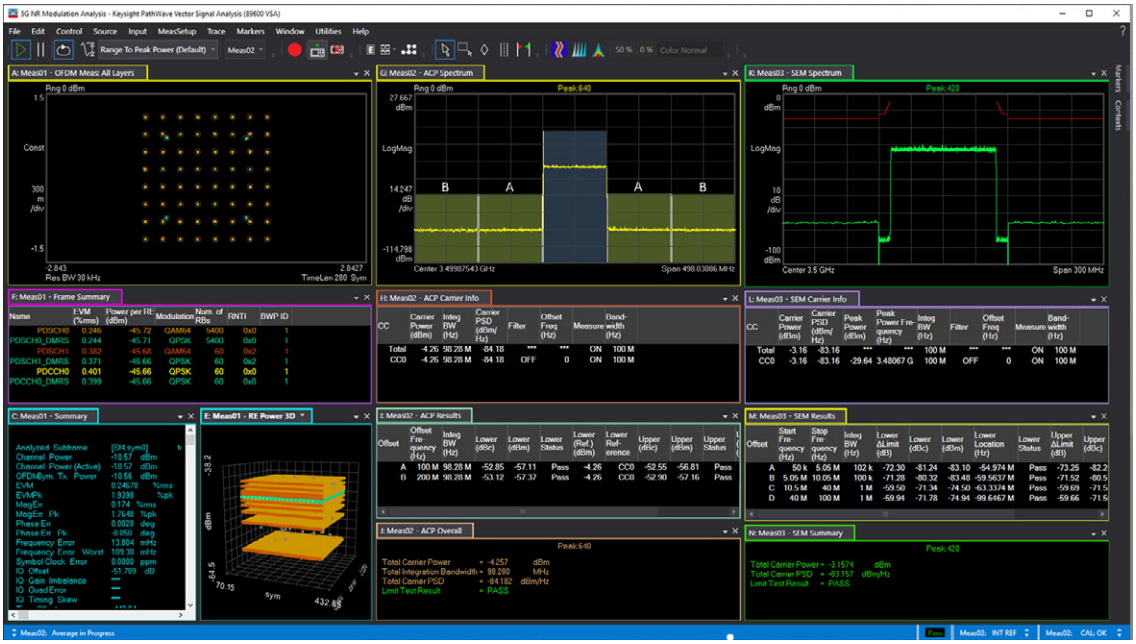
Solution: gNodeB field measurements

Field testing of a 5G gNodeB instance requires more sophistication than a simple five bars indication of signal strength on a device. Understanding reliability requires rigorous signal testing in indoor and outdoor settings, testing while a UE is in motion, and testing voice and video quality. Keysight has two solutions for evaluating quality of service (QoS) and quality of experience (QoE).

Keysight FieldFox is a handheld RF and microwave analyzer for precise QoS measurements. One instrument examines antenna conditions, transmit power, control channel power, RF spurious response, gNodeB parameters, and more. Various models support up to 120 MHz measurement bandwidth at frequencies up to 54 GHz. Real-time spectrum analysis evaluates advanced metrics like EVM, synchronization signal block (SSB) offset, and beamforming performance, helping spot interference or coexistence problems. Over-the-air signal quality measurements include multipath synchronization and coverage area path loss.

FieldFox software is upgradable via the **Keysight FieldFox handheld analyzer software** application. It can export data to **Keysight PathWave Vector Signal Analysis (89600 VSA) software** for deeper offline investigation of measurements.

WaveJudge also works with FieldFox. A slimmer entry-level WaveJudge application allows basic decoding of 5G downlink broadcast channels, while the full WaveJudge Advanced software can do complete protocol stack decoding from FieldFox trace captures.



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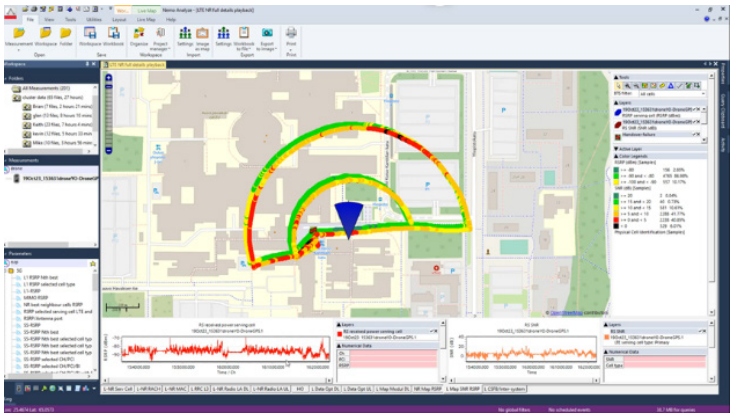
www.keysight.com/find/fieldfox

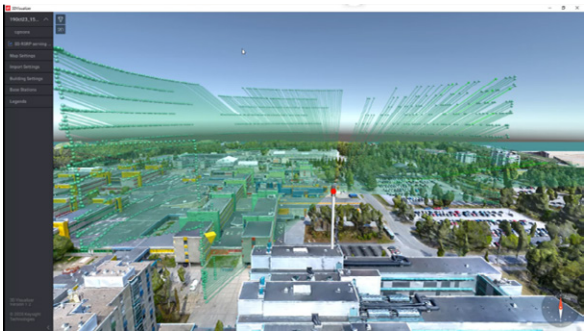
Keysight Nemo wireless network solutions are a family of hardware and software tools for testing QoS and QoE at all stages of deployment, from rollout to ongoing automated monitoring. Three solutions typify capability in the family: Nemo Handy, Nemo Industry Probe, and Nemo Analyze.

Keysight Nemo Handy is an Android application running on phones with Qualcomm or Samsung 5G-enabled chipsets without special firmware or rooting. It performs various diagnostic, QoS, and QoE tests, from real-time voice quality testing per POLQA to application testing. It supports popular commercial applications out of the box and can test agency-specific applications or web browsing from customized automated scripts capturing touch input command sequences. Network QoE assessments use the Network Performance Score (NPS), an ETSI and ITU-T methodology combining key performance indicators into a single metric. Nemo Handy supports indoor mapping with waypoints and vehicle-driven or drone-flight testing using GPS coordinates, with data visualization fed to mapping tools.

Keysight NTP10009A Nemo Industry Probe provides an IP65-rated monitoring device for unattended, remote-controlled measurements in harsh indoor environments. It provides a continuous view of QoS over time, including regression testing for changes and upgrades.

Keysight Nemo Analyze is the desktop software that handles the post-processing of drive or flight data gathered from Nemo or FieldFox measurement tools. Its advanced 5G NR analytics include SSB beam footprints visualized on 2D or 3D maps, attenuation from buildings and trees, and more for a realistic view of coverage.





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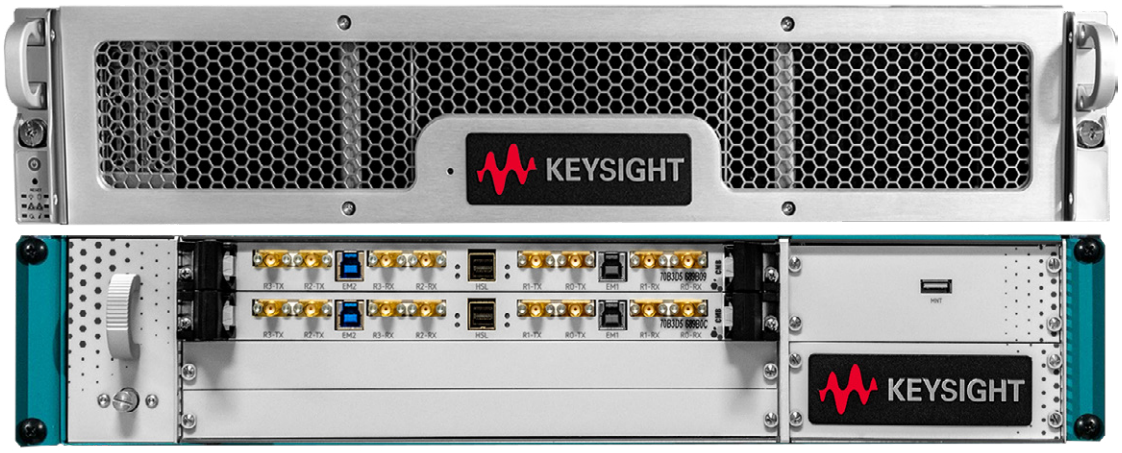
> www.keysight.com/find/nemo

Prepare for Waves of Devices

With gNodeB signaling characterized, traffic is the next 5G network reliability test. End-to-end solutions should simultaneously generate IP traffic simulating voice and data sessions running on thousands of devices to a single gNodeB instance. Priority call testing amid heavy network loading is also essential, especially for disaster response deployments.

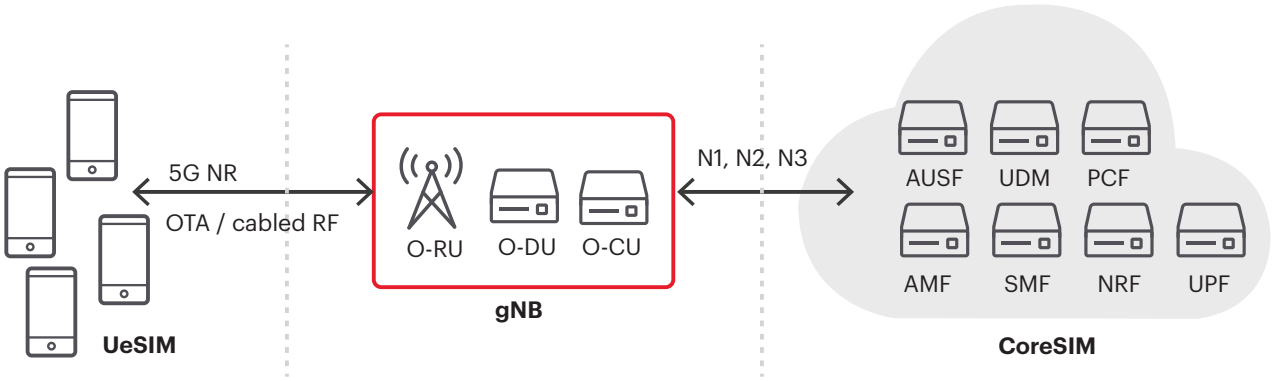
Solution: Scalable UE emulation

Keysight P8800S UeSIM UE emulation scales up to thousands of UEs with expansion via pluggable modules. It simulates popular smartphone application traffic, including multiplay voice, video, and data traffic, with controllable tests covering every layer in the protocol stack from L1 to L7. Individual device signals can fade, emulating mobility for more realism.



Solution: Wraparound core simulation

Keysight P8850S CoreSIM core simulation is a software companion to the UeSIM, running on any Intel-based server and providing a 5G / 4G core simulator for wraparound testing. Eliminating some core network dependencies and controlling others allows testing to focus on devices under test as emulated in UeSIM. It provides a real-time view of hundreds of QoE metrics.



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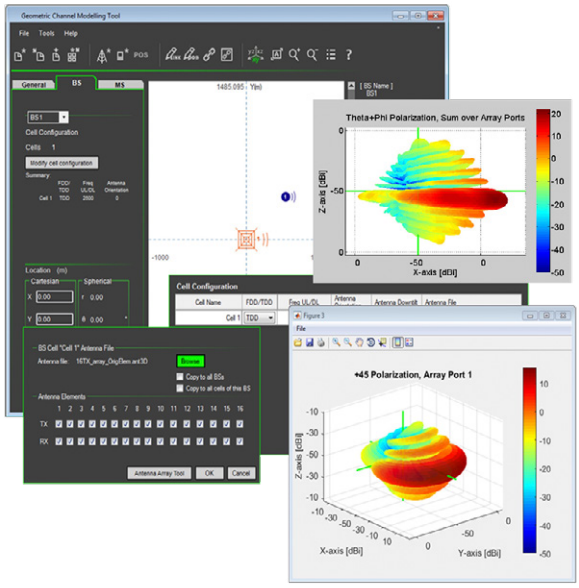
- www.keysight.com/find/uesim
- www.keysight.com/find/coresim

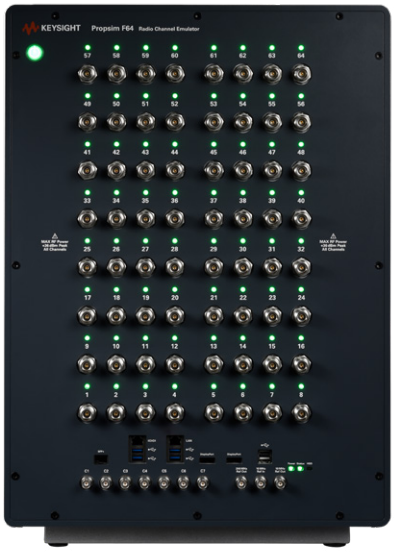
See Channel Variations in Detail

Fading UE and gNodeB signals is a way to approximate simple UE mobility behavior. A comprehensive view of channel variation effects needs a more robust approach. Channels vary widely among urban, suburban, and rural coverage, and indoor and outdoor effects differ. Kinematics also come into play when vehicles move and change their orientation.

Solution: Propagation emulation

Keysight PROPSIM channel emulator platforms emulate impairments in complex 3D real-world conditions. Effects likely seen in a 5G network deployment include dynamic multipath propagation, range path loss and blocking, Doppler shift from mobility, noise, and interference. Tests with realistic signals provide insight into UE and gNodeB performance during location research, deployment planning, and field performance optimization.





PROPSIM platforms control RF signal time, phase, and amplitude on up to 64 transmit channels at frequency ranges to 7.25 GHz with bandwidth up to 1.6 GHz. Using the **Keysight E7770A Common Interface Unit** and the **Keysight M1740A mmWave transceiver** extends the PROPSIM range.

Rather than programming channel behavior by hand, various companion toolsets help users create scenarios. Military-grade 5G network deployments might choose the **Keysight S8825A Satellite and Aerospace Channel Emulation Toolset** for emulating 5G non-terrestrial networks.

Want to Learn More?

> www.keysight.com/find/propsim

Solution: Custom channel modeling

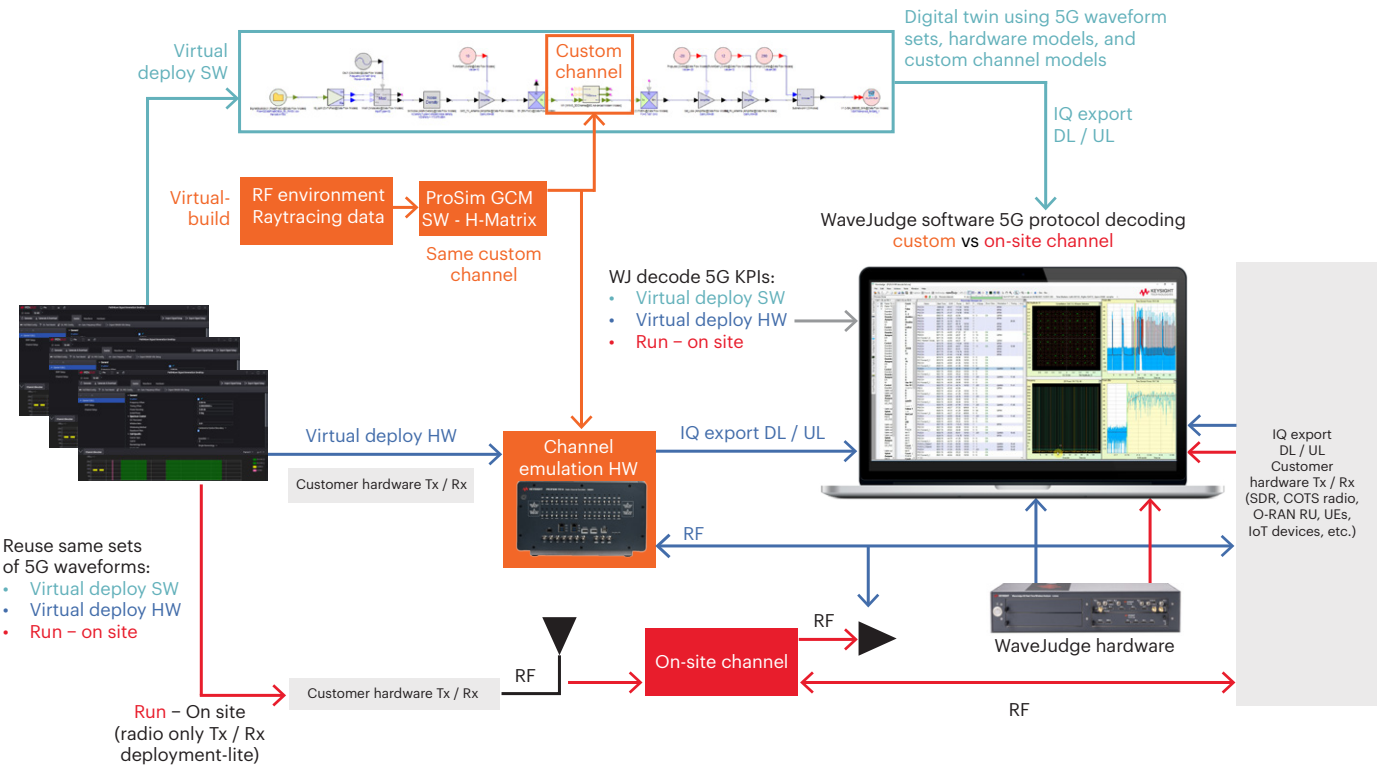
Traditional 4G / 5G network planning uses a static link budget with enough margin added to overcome commonly encountered impairments. Channel modeling assumes propagation through outdoor environments with vegetation and terrain or indoor environments in lightly constructed buildings.

New scenarios, particularly private 5G networks, are changing some of the thinking around channel modeling. Consider a large industrial warehouse, a manufacturing facility, or a more unusual context, like the lunar surface — high-reflectivity environments comprising site-specific materials and object shapes presenting unique channel behavior to gNodeBs and UEs moving within these locations.

Designers can embed customized channel models within a decodable link budget using a combination of PathWave Signal Generation, PathWave System Design, PROPSIM channel emulation, and WaveJudge Advanced software. Teams can see via the virtual simulation how their 5G protocol decode works without extensive physical setups and measurements. Waveforms incorporate reflectivity, delays, and losses, applying ray tracing to create a more detailed channel model. Informed decode performance can help adapt gNodeB signal energy and direction using beamforming.

This custom channel modeling approach provides a higher-fidelity network planning tool than using signal-to-noise ratio to estimate block error rate. It also offers a deterministic method for verifying on-site 5G RF performance instead of using only per-specification 5G waveforms and oversimplified channel models. Fully exercising such a virtual channel model cuts on-site time for physical measurements and network adjustments, getting optimized 5G deployments for application-specific environments up and running faster.

Photo by Lance Cpl. Joseph E. DeMarcus



Virtual-build: Virtual build of channel model from Raytracing data

Virtual-deploy: Virtual deployment = 5G or tactical waveforms + channel model + 5G or tactical protocol decode

Run: Same 5G or tactical waveforms + O-RAN RU or tactical radio + 5G or tactical protocol decode

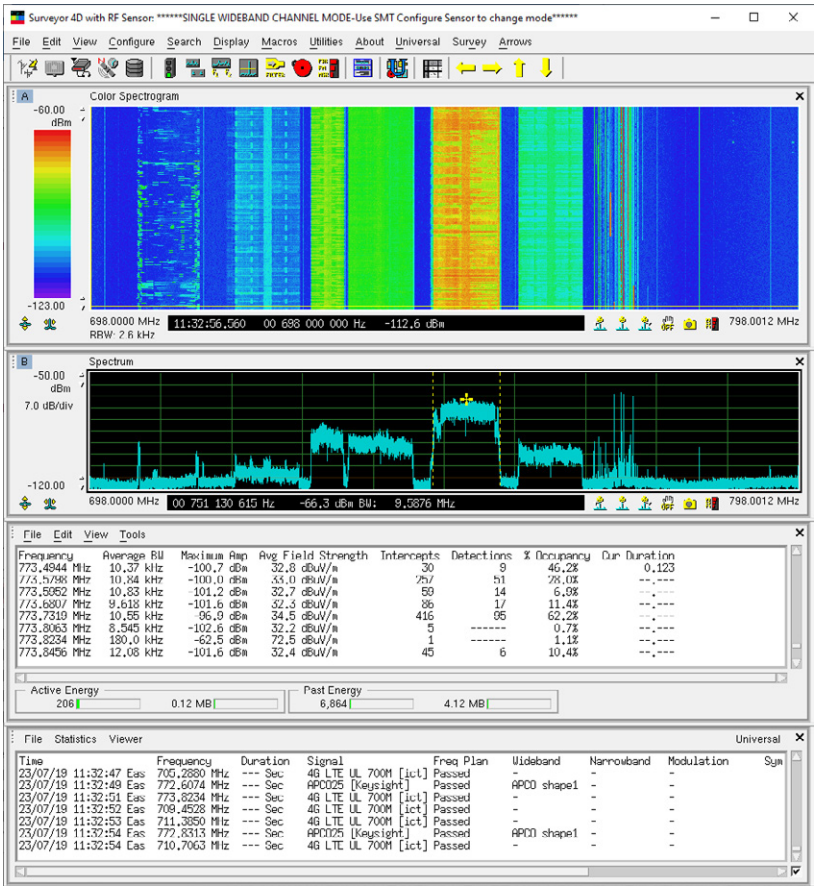
Solution: RF sensors for spectrum monitoring

Spotting interference in a 5G network is one thing. Finding the source, especially in a crowded environment of emitters, is another. Intermittent sources can complicate the problem. Traditional methods of driving around with handheld gear, such as the Keysight FieldFox, may turn up an emitter at the right time. A wide-area search for interference may be time-consuming and hazardous. It may also require observations over an extended time, days or weeks, with 24/7 vigilance, waiting for the right moment to see when interference occurs.

The **Keysight N6841A RF sensor for spectrum monitoring** is a small, rugged platform that users can mount on tripods, roofs, and towers; install in fixed shelters or vehicles; or carry. It requires minimal physical infrastructure (15 to 24 VDC power and an antenna), operates in temperatures of –15 °C to +55 °C, and has no moving parts or indicators for silent, invisible operation. Continuous monitoring can be broad spectrum, or users can apply programmable filtering to zoom in on specific signals.

One sensor can confirm interference; three or more working together can locate it. Triangulation, relative signal strength, time difference of arrival, and more techniques can pinpoint a transmitter in 2D and possibly 3D space. RF sensors use IEEE 1588-based network timing protocols to coordinate a time base. **Keysight N6854A geolocation server software** is a plug-in application that integrates measurements from multiple RF sensors into one portal for visualization.

More powerful military-grade spectrum monitoring, signal collection, and classification become available by adding the **Keysight N6820ES Spectrum Monitoring Surveyor 4D software** to the N6841A RF sensor and N6854A geolocation server software. It performs high-speed, high-resolution spectrum searches with automated tools to aid in classification and powerful triggering and masking functions. A built-in spectrum recorder saves data to a SQL database for long-term logging and analysis. It automatically tasks a network of N6841A RF sensors for precise geolocation.



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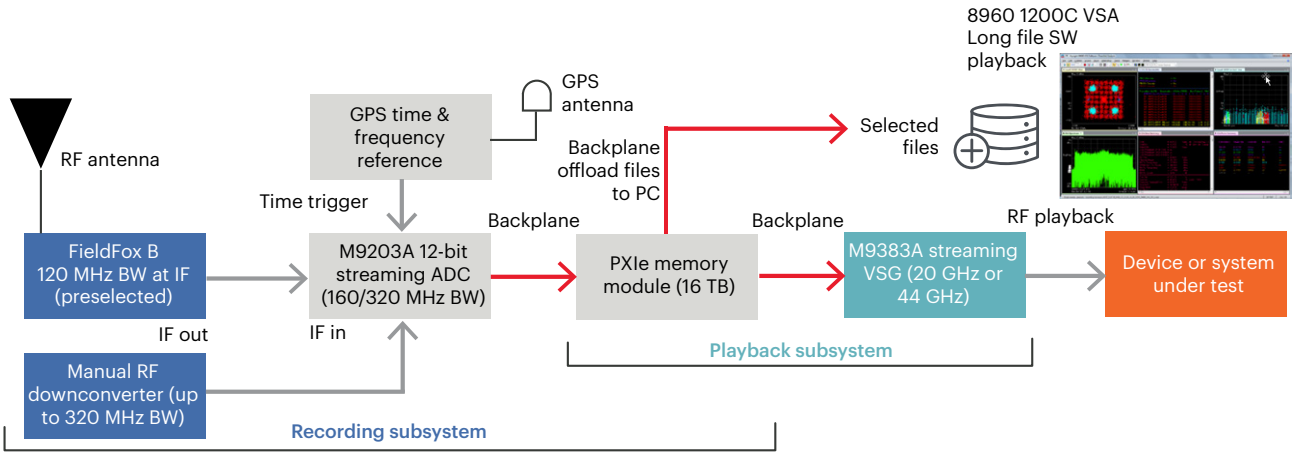
- www.keysight.com/find/rfsensor
- www.keysight.com/find/N6854A
- www.keysight.com/find/N6820ES

Solution: Record and playback

Record and playback functions are helpful in other situations, such as accurately emulating an RF environment, investigating sporadic or continuous interference, or testing system performance with realistic channel impairments. The **Keysight S7980A record and playback solution** pairs a FieldFox Model B operating in microwave downconverter mode with data acquisition and playback hardware in a portable PXIe chassis.

FieldFox provides strong preselection with 120 MHz of acquisition bandwidth for frequencies up through 5G NR FR2. A **Keysight M9203A digitizer** paired with a PXIe 16 TB memory module provides the long capture capability; a PXIe GPS time and frequency reference handles triggering and time-stamping. Playback occurs through the **Keysight M9383A vector signal analyzer**.



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Prove the Network Infrastructure

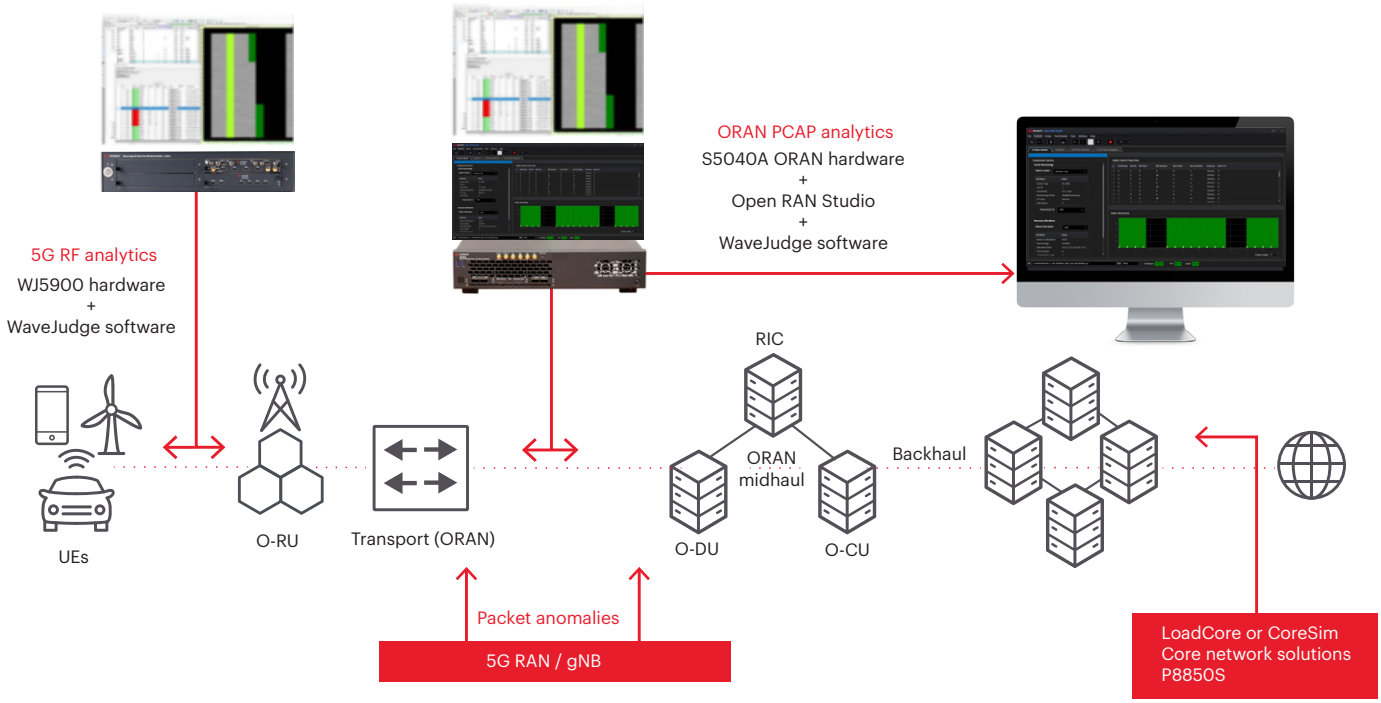
After evaluating UEs, gNodeBs, and channels, attention turns to the remaining 5G network domain: the radio access network and core network infrastructure. Where testing in the other domains sought to characterize RF behavior, core network performance is about configuring and assessing compute architecture. As its name implies, the RAN controls the 5G NR interface. The core network interfaces with RANs to aggregate data traffic, deliver network services, and interface the 5G network to internet transport.

Decisions made in the core network architecture impact QoE, the performance of critical network services, and security for the network and its users. Three areas of testing help inform better decisions about resources and configurations.

Solution: Disaggregated RAN emulation

5G network architecture ushered in the disaggregation of the RAN. Instead of a centralized architecture where scalability quickly reaches limits, 5G allows the splitting of functions, with a centralized unit (CU) and one or more distributed units (DUs). A CU handles non-real-time operations at Layers 2 and 3, where DUs are responsible for real-time Layer 1 and 2 operations. Virtualization shifts compute power from dedicated, specialized baseband processing hardware into a mix of general-purpose servers placed at the edge or in the cloud. Scalability occurs by adding DUs and partitioning services across them, ensuring that applications get resources for real-time determinism.

Keysight Open RAN Architect (KORA) is a family of integrated solutions for conformance, interoperability, performance, and security testing of a disaggregated RAN architecture. **Keysight U5040B Open RAN Studio** constructs and measures traffic over a front-haul Ethernet interface and integrates with PathWave Signal Generation for 5G NR for authentic waveforms.



Using the **Keysight S5040A Open RAN Studio Player and Capture Appliance**, together with the WJ5900, Open RAN Studio, and WaveJudge Advanced software, enables a unique capability for Open RAN front-haul integration testing, such as tracing an energy gap from an RF performance disruption as it proceeds through Open RAN stages. Both software tools consume the same PCAP captures for correlated analytics between the Open RAN and the 5G protocol stack.

Users can emulate and test the Open RAN midhaul functions in software with the **Keysight P8826S DuSIM DU emulation** and the **Keysight P8827 CuSIM CU emulation**.

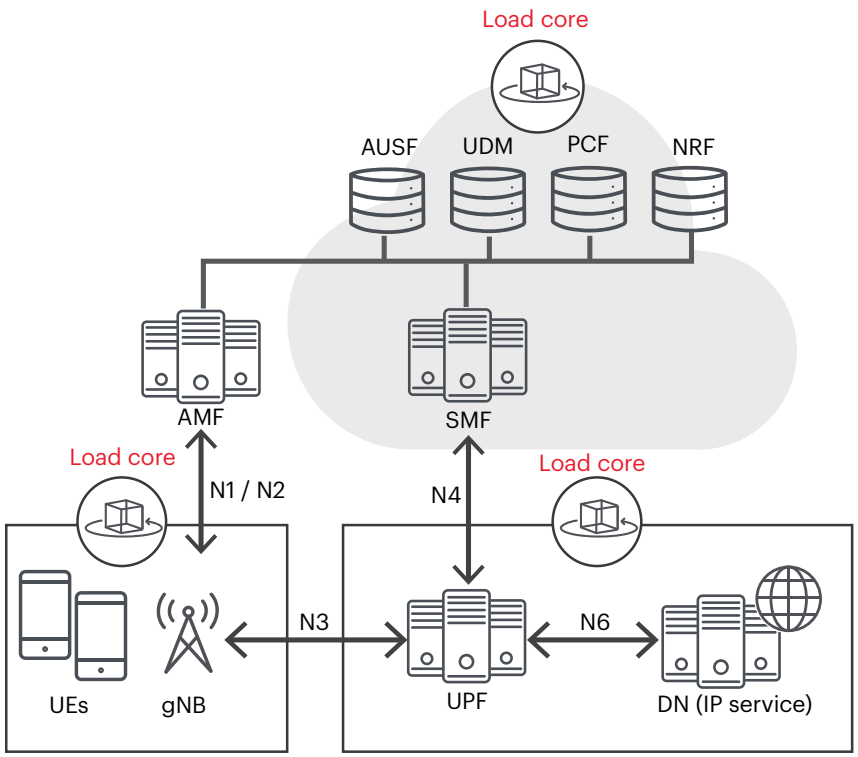
- DuSIM scales to hundreds of DUs and thousands of UEs, delivering tens of gigabits of throughput.
- CuSIM accepts multiple DUs and provides a wraparound testing option with **Keysight P8822S RuSIM UE / O-RU Emulation** for O-RAN fronthaul emulation and a RU+DU wraparound testing option with P8800S UeSIM UE emulation.

Want to Learn More?

> www.keysight.com/find/kora

Solution: Core network load testing

Complex service-based architecture scenarios are where **Keysight LoadCore** shines. It simulates UE behavior in multiple use cases, including network slicing, multi-access edge computing offloading and latency, and video optimization. LoadCore scales up to millions of subscribers using stateful application traffic mixes and can interact with physical servers in the loop.



Want to Learn More?

> www.keysight.com/find/loadcore

Solution: Network security testing

Cybersecurity is a priority for any military-grade system. With 5G network resources split across servers and cloud platforms, network security principles honed from large-scale enterprise IT environments apply to military-grade 5G network security testing.

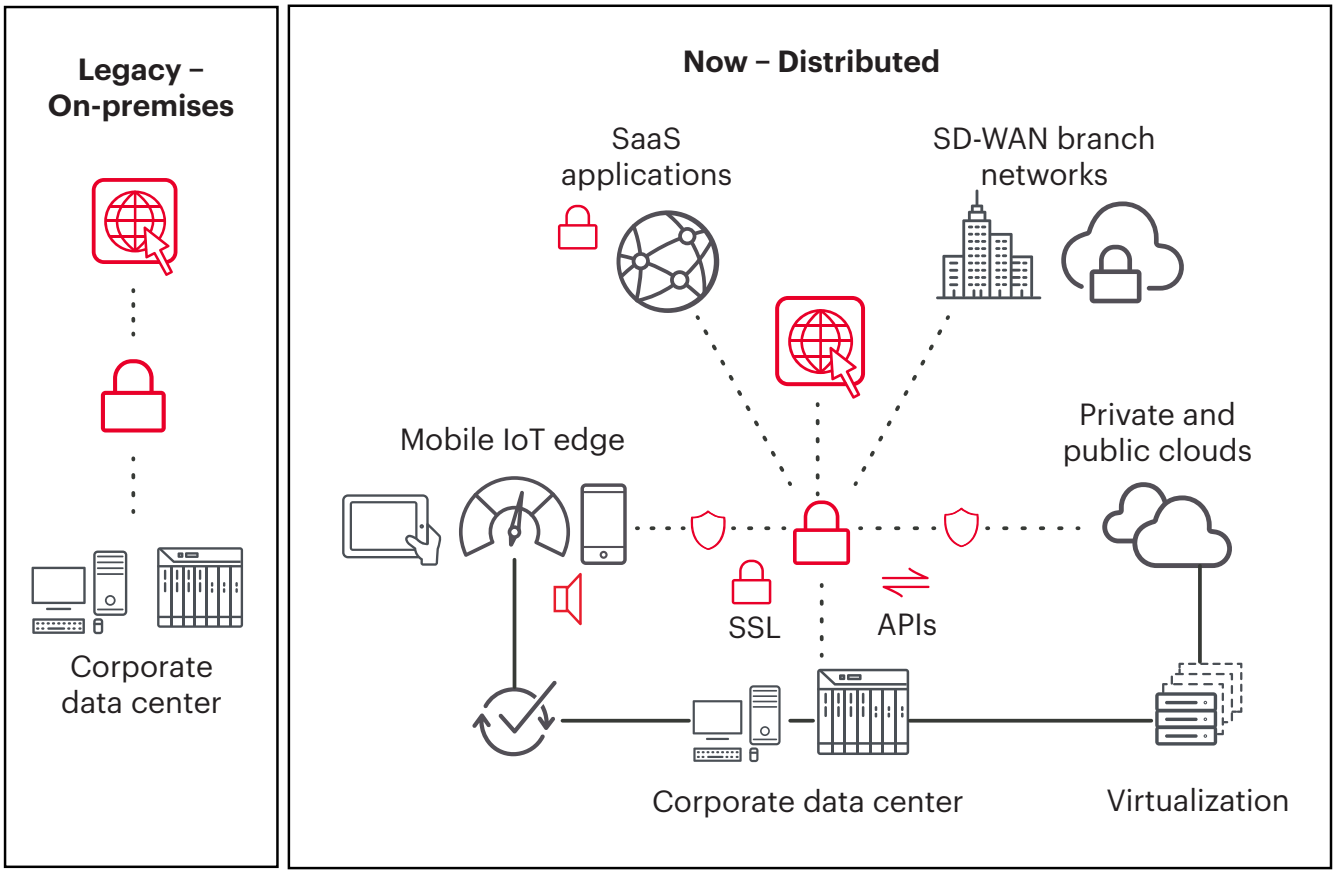
Keysight BreakingPoint focuses on traffic generation, simulating nearly 500 real-world protocols and more than 60,000 attack and malware threats, with protocol customization and manipulation down to the raw data level. Stackable appliances deliver scalability up to 2.4 Tbps throughput from 1.44 billion simultaneous sessions mixing legitimate traffic and distributed denial-of-service attacks, fuzzing, and other exploits.

Keysight IxNetwork provides comprehensive MACsec testing at Layers 2 and 3 for high-speed Ethernet. It performs hardware-based encryption at line speeds for validating throughput, continuity during encryption key rotation, and stability in adverse conditions.

Keysight IxLoad tests application delivery and QoE at Layers 4 through 7, modeling dynamic user behavior. It emulates web, video, voice, storage, VPN, encapsulation / security, and more in creating realistic scenarios. Real-time metrics help drill down to find network degradations and bottlenecks.

U.S. Navy photo by Clinton Beaird/Released

Military systems are often systems of systems distributed across platforms connected by high-speed networks. **Keysight CyPerf** replicates a distributed network faster and more accurately using lightweight agents to model dynamic application traffic, user behavior, and threat vectors.



Want to Learn More?

- www.keysight.com/find/breakingpoint
- www.keysight.com/find/ixnetwork
- www.keysight.com/find/ixload
- www.keysight.com/find/cyperf

Visualize It All in Virtual Space

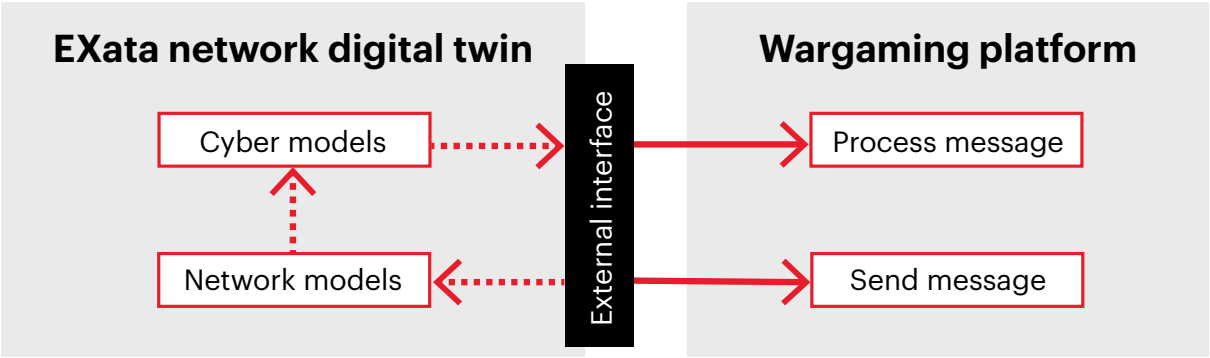
Moving engineering tasks into virtual space creates a shift left, enabling the exploration of designs in real-world detail using modeling and simulation. Virtual space works before physical prototypes exist or when physically re-creating real-world conditions is cost-prohibitive, time-consuming, or impractical.

Two virtual engineering concepts can aid military-grade 5G network deployment:

- Model-based system engineering (MBSE) is a methodology connecting requirements to system architecture, moving away from a document-centric approach.
- Digital twins extend the MBSE concept with measurement science. A true digital twin is more than a virtual prototype. It accurately mirrors the behavior of a physical system using ongoing observations with necessary enhancements to models and simulations over its life cycle.

Solution: Network digital twins

Designed for networks with servers, radios, and sensors, **Keysight EXata network modeling** builds on MBSE to create a network digital twin in a software virtual network. It interoperates with radios and devices for hardware in the loop and connects to systems running real applications.



One military-grade use case for EXata is wargaming, where scenarios run against the network digital twin autonomously or interactively. A human-in-the-loop interface allows a Red Force to inject cyberattacks, while a Blue Force responds to protect mission integrity.

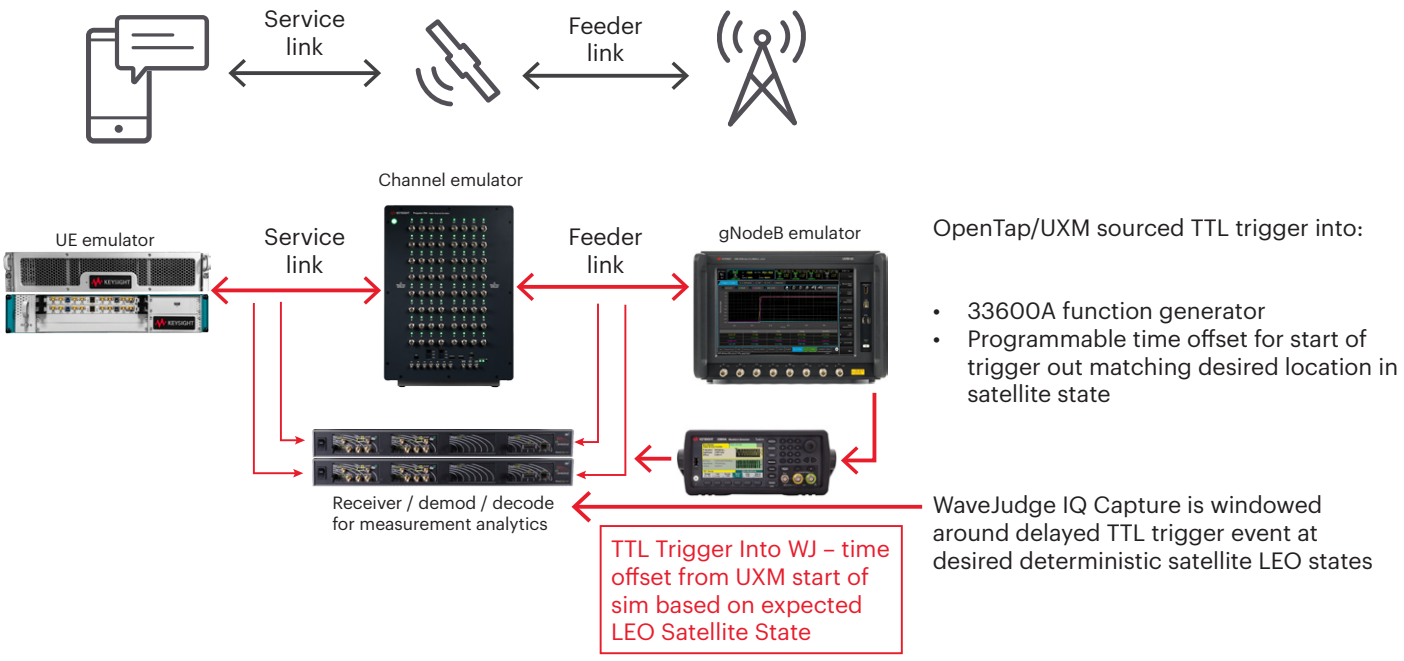
EXata delivers real-time simulation speed without compromising the accuracy of results, allowing teams to assess performance and reduce risks faster without complex staging requirements.

Want to Learn More?

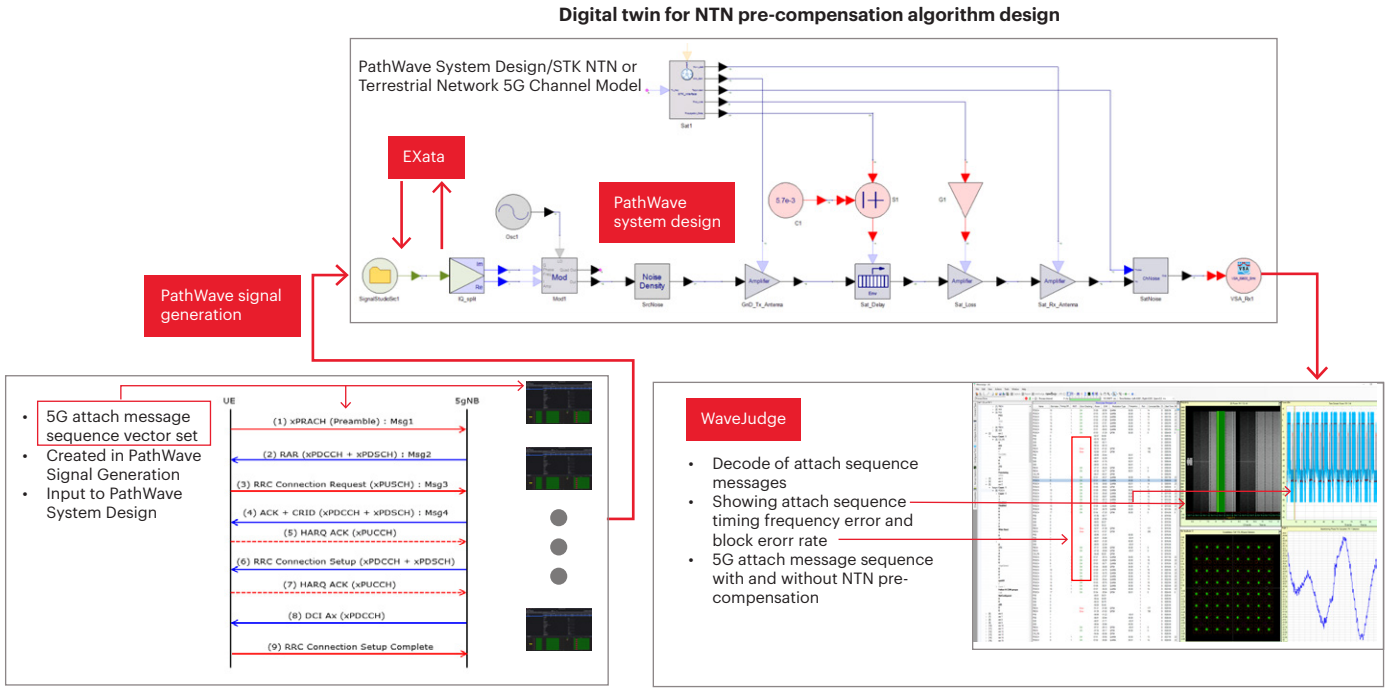
> www.keysight.com/find/exata

Solution: End-to-end 5G NTN simulation

Combinations of these Keysight test and simulation solutions can unlock significant new capabilities. One example is creating an end-to-end 5G non-terrestrial network simulation for exploring Doppler shift. Using hardware emulation for the UE, channel, and gNodeB domains, plus a function generator triggering signals at specific times, WaveJudge Advanced performs complete real-time protocol stack decoding. Doppler pre-compensation algorithm designs start with a digital twin combining EXata, PathWave System Design and STK, PathWave Signal Generation, and WaveJudge Advanced.



The digital twin provides a detailed view of power and signal-to-noise ratio as satellites move and change states, compensating for Doppler shift effects. Staging this kind of test in physical space would be onerous, but it becomes achievable in virtual space with Keysight solutions.



Achieve Performance and Reliability Faster

Whether the mission is tactical warfighting, rescue and relief after disasters, or networking sensors and devices to obtain data, military-grade 5G networks provide effective connectivity. To speed up reliable 5G deployments in these applications, it is best to decompose the network in virtual space, then simulate critical subsystem interactions under real-world conditions. Simulations guided by physical measurements deliver authenticity, and users can quickly verify performance when they physically reassemble pieces at their destination in context.

Measurement science aligning virtual and physical engineering efforts makes all this possible. Keysight's leadership in 5G test and simulation solutions enables chipset and component manufacturers, equipment manufacturers, and service providers across the 5G ecosystem. Through participation in 3GPP, the O-RAN Alliance, the Global Certification Forum, and other standards bodies, Keysight authors hundreds of standards contributions and creates advanced test beds for research and validation. Military-grade 5G networks can rely on the experience and breadth of Keysight for testing UEs, channel propagation and coexistence, gNodeB instances, core network performance and security, and more.

For more information on Keysight's 5G test and simulation solutions, please visit: 5G Device Test Solutions.

Keysight enables innovators to push the boundaries of engineering by quickly solving design, emulation, and test challenges to create the best product experiences. Start your innovation journey at www.keysight.com.