

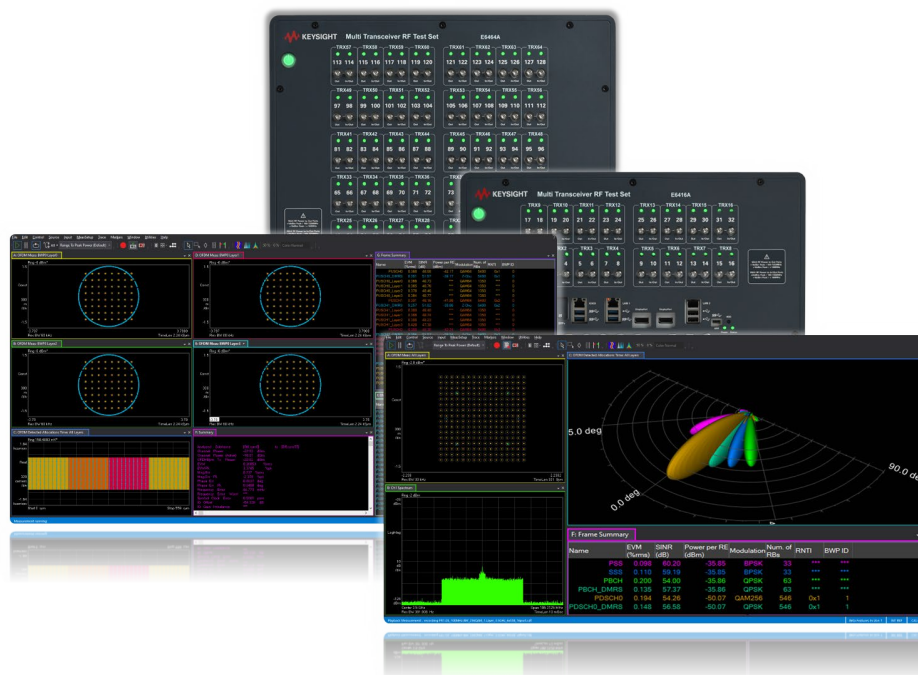
# S9160A Massive MIMO and MIMO RF Beamforming Test Accelerator

Quick and easy massive MIMO and MIMO RF Beamforming validation of RAN and O-RAN based 5G radios

## Introduction

Massive Multiple-Input, Multiple-Output (mMIMO) is the key technology in delivering the promises of 5G as it enables drastic improvements in cell throughput without need for additional spectrum. mMIMO capable 5G base station forms user specific 3-dimensional spatial RF signal beams to co-schedule data streams in uplink and downlink towards multiple users in same time and frequency resources.

S9160A Massive MIMO and MIMO RF Beamforming Test Accelerator is a scalable multi-port RF test solution designed and validated for 5G RAN or O-RAN base station and Radio Unit testing. The solution is addressing testing needs in 5G radio design workflow from antenna integration, L1/L2 beam scheduling, end-to-end functional multi-user beamforming validation of live network base station with multiple User Equipment (UEs). Solution is extendable to support 3GPP 5G NR base station conformance tests and O-RAN Alliance defined O-RAN Radio Unit conformance tests including beamform tests. Tier-1 equipment and network operators use today S9160A Massive MIMO and MIMO RF Beamforming Test Accelerator to ensure their Massive MIMO capable networks operate at the highest performance level.



# Massive MIMO RF Testing Challenges

Implementation of mMIMO dynamic beamforming requires complex hardware and software algorithms that all are necessary to test and verify across the workflow. Figure 1. illustrates example workflow for mMIMO base station from development to deployment phase.

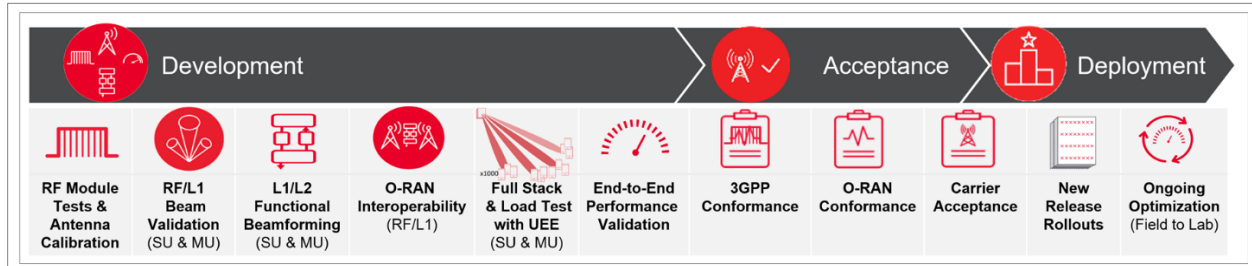


Figure 1. mMIMO capable O-RU and gNodeB workflow

The key testing phases are:

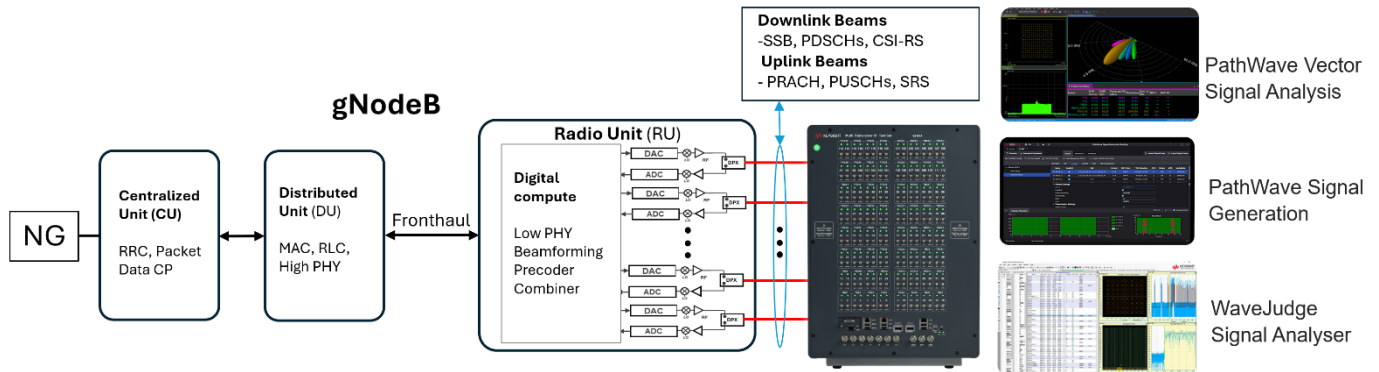
- Massive MIMO Antenna Array calibration and integration to radio unit
- PHY/L1: validating RF parameters, beam weights, beam patterns, beam steering, and single- and multi-user beams
- L1/L2: functional beamforming for single- and multi-user beams, pre-coding uplink SRS based downlink beams, and dynamic beamforming e.g., user tracking.
- Interoperability of an O-RAN base station: Radio Unit (RU), Distributed Unit (DU) and Central Unit (CU) from different manufactures
- RF beamforming in a connected mode end-to-end with real user equipment

**Testing mMIMO RF beamforming base stations requires a test solution that is capable of measuring phase and time coherent RF signals across all base station transmit and receive antenna ports at once. These requirements lead us to the following questions:**

- How to decrease the time and cost of testing increased by the number of mMIMO base station RF antenna ports?
- How to calibrate a complex multiport test system for phase, time, and amplitude?
- How to guarantee consistent results across the design workflow test stages for cross-correlation and quick error solving?

# S9160A Massive MIMO and MIMO RF Beamforming Test Accelerator

S9160A consists of Keysight's E6464A or E6416A Multi Transceiver RF Test Set (MTRX) integrated with Keysight's PathWave Vector Signal Analysis software for downlink PHY/L1 measurements and PathWave Vector Signal Generation software for uplink waveform generation.



**Figure 2.** RF conducted test of 5G mMIMO and MIMO base station and/or Radio Unit

MTRX platform features phase and time coherent sampling of all base station downlink antenna ports (from 4 up to 64 depending on the configuration) in a single instant snapshot and simultaneous generation of uplink waveforms and spatial beams to test all base station uplink antenna ports (4 – 64) instantly as depicted in Figure 2.

S9160A solution uniquely enable quick and easy mMIMO radio/gNodeB testing in development, acceptance, and deployment workflow phases. With specific configuration and options following test and measurements are supported:

- Antenna Array and Radio Unit beam weight calibrations in uplink and downlink
- Downlink beam weight measurements and uplink beam measurements.
- L1 precoder and combiner testing
- Connected mode beams: downlink CSI-RS, uplink SRS etc.
- Single- and multi-user beams in downlink and uplink
- Uplink SRS based downlink beam control scheduling etc.
- O-RU interoperability with O-DU(+O-CU)
- End-to-end functional beamforming tests connected to multiple user equipment (UEs)
- 3GPP conformance in-band tests for 5G NR base station (requires P7000A SW)
- O-RAN conformance tests for O-RU (O-DU emulator, test automation and test suites required)

## Who benefits from using the S9160A solution?

Network equipment manufacturers including O-RAN radio unit manufacturers to

- test and verify RF characteristics of RF beams in uplink and downlink (RF, L1/L2)
- validate new 5G beamforming features and bug fixes.
- optimize base station performance.
- assess 3GPP conformance and O-RAN O-RU conformance and interoperability.

Mobile network operators to

- validate and optimize network equipment manufacturers' base station beamforming functionality and performance parameters.
- benchmark base station manufacturers' product performance.
- verify new network radio units prior to market launch and assure radio units' interoperability with the local network configuration.

Test houses, system integrators and OTIC laboratories to

- test multi-vendor interoperability.
- test, optimize, and benchmark base station manufacturers' product performance and interoperability.

## What does the S9160A solution offer?

The solution offers:

- Integrated and scalable RF test solution for MIMO and mMIMO RF beamforming testing.
- MIMO 4TR, 8TR, 12TR, and 16TR, mMIMO 16TR, 32TR, and 64TR instant multiport RF MIMO beamforming measurements or RF beamforming measurements.
- Tools to examine the performance of users or signals, with up to 8x8 spatial multiplexing MIMO or up to 64 port massive MIMO beamforming.
- Scalable from value for money sequential testing to full array testing.
- Full set of beam weights, beam shapes, and RF parametric instantly downlink signals.
- Keysight's advanced measurement applications to pinpoint beamforming problems.
- PathWave Vector Signal Analysis (89600 VSA) application for demodulation and vector signal analysis.
- PathWave Signal Generation (PWSG) for 5G NR application enables easy and quick testing of uplink receiver beamformer in L1/L2 mode for single and multi-user cases.

**S9160A solution capabilities can be extended with**

- WaveJudge Wireless Analyzer software for L1-L3 protocol decoding and PHY analysis ([SJ001A](#)).
- Open RAN Studio software for O-RU Testing and Validation suite ([U5040BSCB](#)).
- O-RAN Radio Unit Test Automation Solution (including O-RAN Conformance testing) ([P705xA](#)).
- Base Station Measurement Automation Solution (including 3GPP Conformance testing) ([P7000A](#)).

# Hardware Components



Figure 3. S9160A hardware components

Keysight's S9160A Toolset is built around the scalable E6464A or E6416A MTRX platforms, Figure 3. E6464A is available in scalable RF transceivers from 8, 16, ... up to 64 RF transceivers and E6416A from 4TRX to 16TRX in a single RF test instrument.

## S9160A Key Software Components

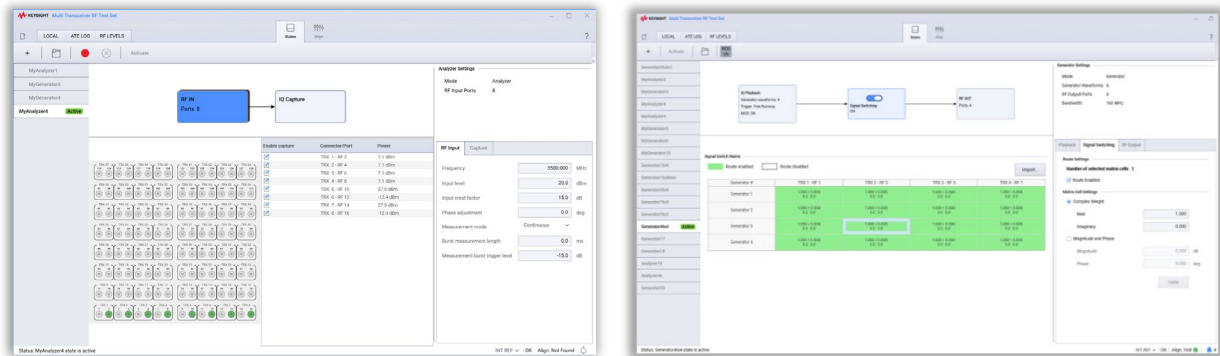
### Multi transceiver RF Test Set Application

Test Set Application is for controlling MTRX signal analyzer, signal generator, and signal pass through testing. Each testing modes have their own settings like RF, signal switching matrix, triggers, waveform selection, signal levels settings and calibration.

The RF Test Set Application offers tools to:

- MIMO 4TR, 8TR, 12TR, and 16TR as well Massive MIMO 16TR, 32TR and 64TR instant multipoint RF MIMO beamforming measurements or sequential MIMO and Massive MIMO RF antenna port beamforming measurements
- 8x8 spatial multiplexing MIMO or up to 64 channels massive MIMO (mMIMO) and beamforming
- Measure and generate downlink/uplink RF/L1 beam weights, beam shapes and signals.
- Measure all beam weights, beam shapes and signals instantly in both uplink and downlink.
- See through complex signals and beams in uplink and downlink with extendable PathWave Signal Analyzer
  - SSB, PDSCH, CSI-RS, antenna port-specific beam weights, and 3D beam shapes
  - Uplink PRACH, PUSCH, SRS

- Uplink SRS based downlink massive MIMO scheduling test.
- Single and Multi-User beamforming test. Various traces are available to look at per layer and per port modulation quality, as well as power, time, frequency, and phase.

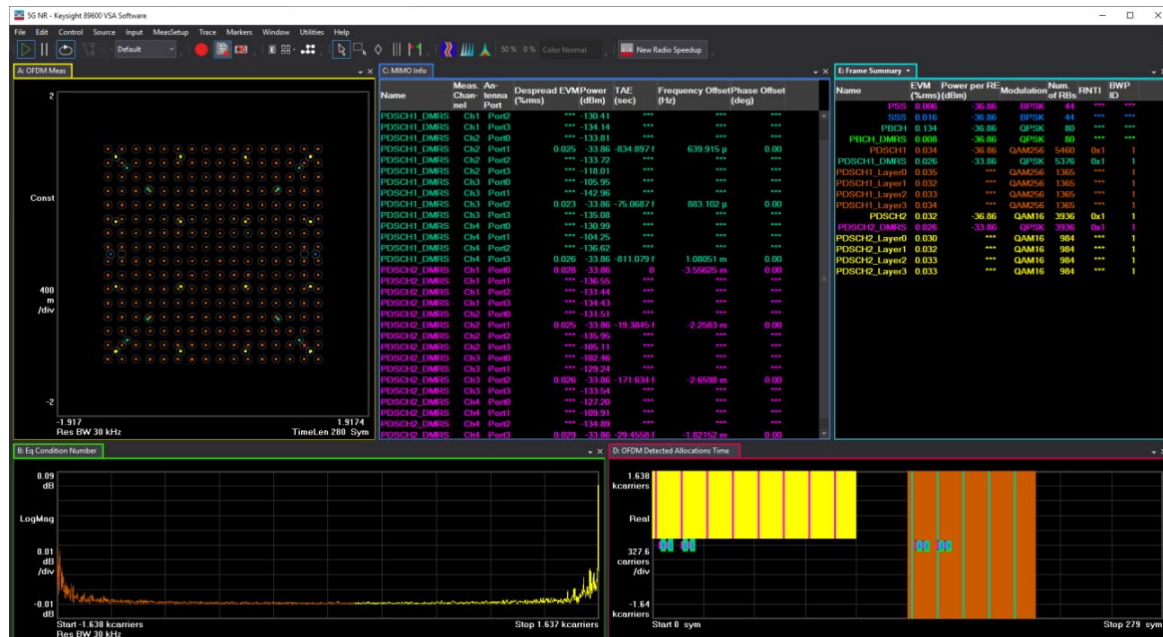


• **Figure 4.** Multi Transceiver RF Test Set Application for configuring the solution.

## PathWave Vector Signal Analysis

**PathWave Vector Signal Analysis (89600 VSA) application** (89601200C and 89601BHNC) allows you to see through the complexity of 3GPP 5G New Radio (NR) signals with a comprehensive and forward compatible set of tools for demodulation and vector signal analysis.

It also enables to examine performance of users, or signals, with up to 8x8 spatial multiplexing MIMO or up to 64 channels Massive MIMO (mMIMO) and beamforming. Various traces are available to look at per layer and per port modulation quality, as well as power, time, frequency, and phase.



**Figure 5.** Example of 4 channel 5G NR downlink MIMO measurement

The MIMO Information table shown in Figure 5 (Trace C) includes per channel performance as well as cross channel performance metrics. EVM for each antenna port is reported. In addition, per path power at each antenna port plus time, frequency and phase offset of the physical channel is reported for each path. Cross-channel performance can be characterized by looking at cross coupling and relative phase, timing, and power. A condition number trace (Trace B) is also available to view the impact of the MIMO channel.

Massive MIMO and beamforming with up to 64 antenna ports, with beam weights and beam pattern results are available for SSB, CSI-RS, PDSCH in downlink.

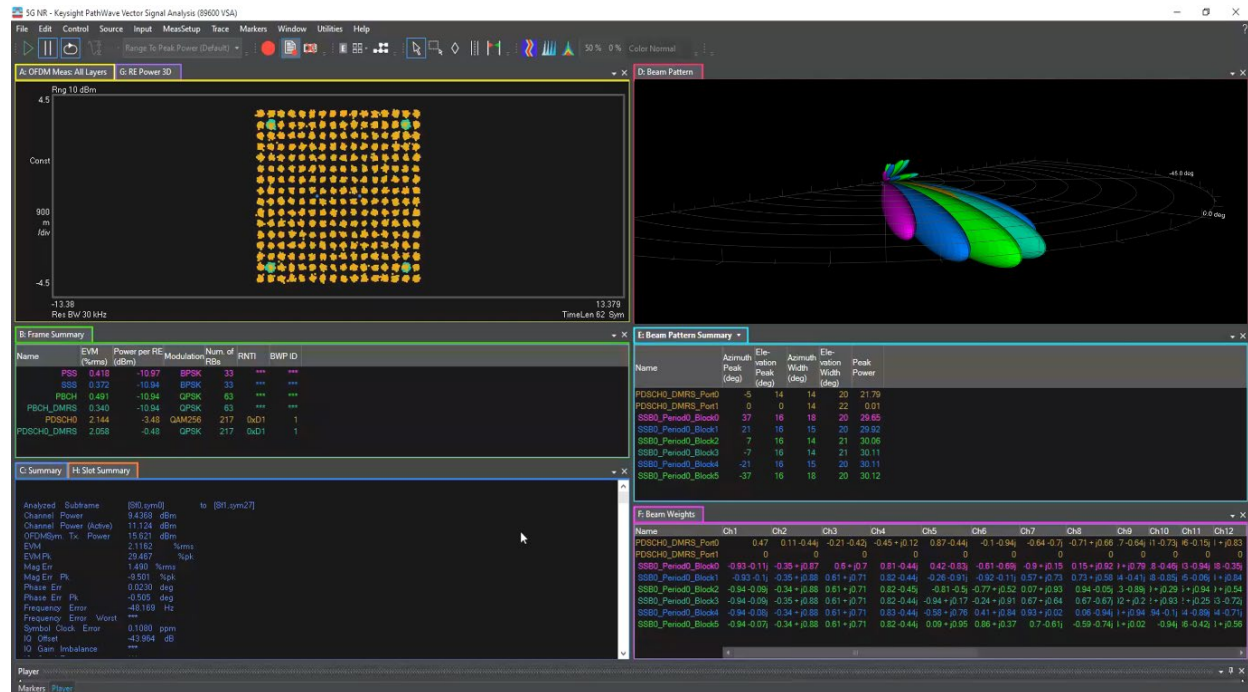


Figure 6. Example of downlink beamforming with magnitude and phase weightings and corresponding beam patterns, EVM figures.

## PathWave Signal Generation for 5G NR

PathWave Signal Generation (PWSG) for 5G NR (N7631EMBC) application features generation of 3GPP Rel 15, Rel 16 and Rel 18 standard-compliant 5G NR signals for testing base station with channel coding and multi-antenna port support. PWSGs multi-user channel generation enables easy and quick testing of uplink receiver beamformer in L1/L2 mode for single and multi-user cases with MTRX.

With PWSG S9160A provides programmable digital spatial weight matrix e.g., 1x8, 1x16, 1x32 up to 16x64 for testing single and multi-user beamforming. MTRX provides built-in calibration tool for easy end-to-end calibration steps to ensure phase and amplitudes across different RF chains are aligned. RF beamform test option is to test Base Station in live network configuration with User Equipment.

## Extend to Keysight's WaveJudge Analyzer software

Keysight's **WaveJudge Analyzer Application** software for optimizing and troubleshooting beamforming algorithms. WaveJudge analyses beam weight coefficients in UL/DL and provide full-stack L1/L3 protocol cross-correlated analysis. WaveJudge enable RF beam measurements on live signals and enables RF beamforming measurement in low SNR conditions providing High dynamic range for testing.

WaveJudge is capable to provide 3GPP RF and protocol analytics from both RF and O-RAN fronthaul interface. This enables user to correlate the results between these two interfaces and identify the root cause for the potential issue.

## Extend to wrap around MIMO and Massive MIMO O-RU testing

Keysight's **Open RAN Studio (ORS)** softwares are powerful tools to O-RAN focused testing. With ORS customer can construct, play, capture, and measure O-RU behavior in different test cases. The ORS will bring comprehensive testing coverage for DL/UL and beamforming analysis. It expanded fronthaul throughput to address massive MIMO testing.

With Keysight's **Time Sync Analyzer (TSA)** O-RU is controlled to create defined testing beams as well received beams and signals created by E6416A or E6464A MTRX.

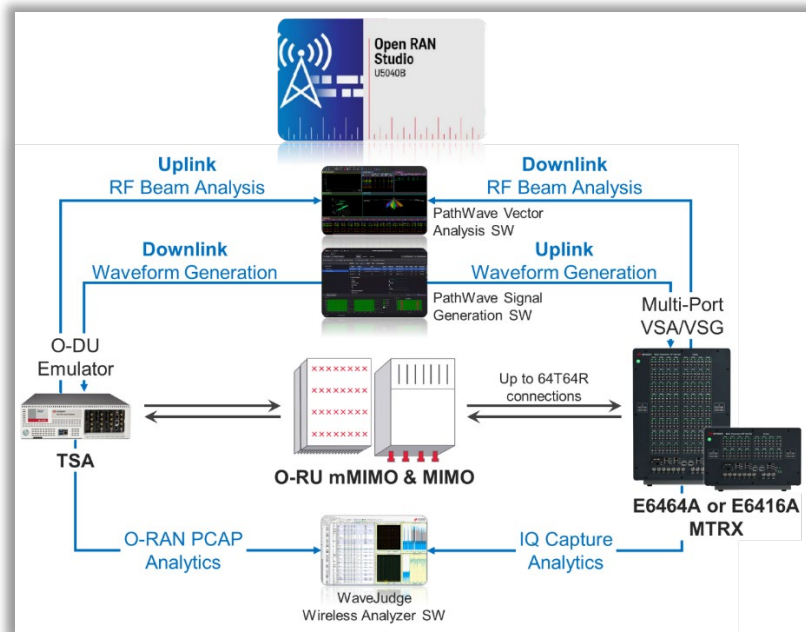


Figure 7. Keysight's wrap around MIMO and mMIMO O-RU testing solution



# Keysight Wireless Solutions

Keysight's wireless end-to-end design and test solutions enable the mobile industry to accelerate wireless product design development from the physical layer to the application layer and across the entire workflow from simulation, design, and verification to manufacturing, deployment, and optimization.

Keysight offers common software and hardware platforms compliant to the latest 3GPP and O-RAN standards, enabling the ecosystem to validate wireless technologies quickly and accurately. You can test chipsets, devices, base stations, and networks, as well as emulate subscriber behavior scenarios.

## Resources

### For more information

- S9160A 5G Massive MIMO RF Test Accelerator: [www.keysight.com/find/S9160A](http://www.keysight.com/find/S9160A)
- MTRX E6464A and E6416A data sheets
- 89601200C PathWave Vector Signal Analysis Base Platform: [www.keysight.com/find/89601200C](http://www.keysight.com/find/89601200C)
- 89601BHNC PathWave VSA 5G NR Modulation Analysis software: <http://www.keysight.com/find/89601BHNC>
- N7631EMBC PathWave Signal Generation for 5G NR: [www.keysight.com/find/N7631EMBC](http://www.keysight.com/find/N7631EMBC)
- SJ001A WaveJudge Wireless Analyzer Toolset software: [www.keysight.com/find/SJ001A](http://www.keysight.com/find/SJ001A)
- U5040BSCB Open RAN Studio for O-RU Testing and Validation: [www.keysight.com/find/U5040BSCB](http://www.keysight.com/find/U5040BSCB)
- Time Sync Analyzer (O-DU emulator): [www.keysight.com/find/TSA](http://www.keysight.com/find/TSA)
- P705xA O-RAN Radio Unit Test Automation Solution: [www.keysight.com/find/P705xA](http://www.keysight.com/find/P705xA)
- P7000A 3GPP Base Station Conformance (based on 3GPP Chapter 6, 7 and 8) Measurement Automation Solution Software: [www.keysight.com/find/P7000A](http://www.keysight.com/find/P7000A)

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