SOLUTION BROCHURE

5G New Radio Test UE Solution

CONTENTS

5 May 2020

Solution Overview

5G New Radio Release 15 Test UE

The latest generation of cellular communications standards for 5G are significantly more complex than previous generations. Engineers and researchers need standards compliant hardware for testing and validation of new cellular technology in both a lab and field environment, but limited options are available in the early phases of production and deployment. The NI 5G New Radio (NR) Test UE is a fully standards compliant UE built on Software Defined Radios (SDRs) to provide a feature rich and software upgradeable solution.

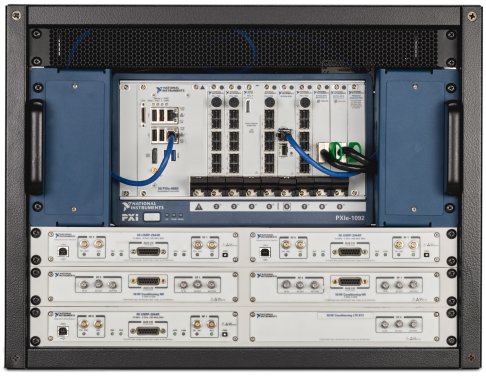

Figure 1: Sub 6 GHz 5G NR Test UE

Creating standards compliant testbeds is crucial to bring new 5G technology to market. Unlike previous generations of standards, new 5G technology spans far beyond base stations and handsets. New application verticals have been defined for 5G, and the Release 15 specification is a baseline for those applications, including heavily hyped applications like augmented and virtual reality, V2X, and smart factories. Being able to access standards compliant systems without needing to rely on semiconductor-based solutions gives researchers the ability to start developing these complex applications sooner than if they needed to wait for silicon. The flexibility and full performance of a test UE also reduces development time by giving users access functionality that isn't available with other 5G NR compliant systems.

The non stand alone (NSA) mode of 5G New Radio uses LTE as an anchor for the control, as shown in *Figure 2*. The 5G NR Test UE runs both the LTE stack and 5G NR stack to enable NSA mode. For both the NSA and SA version, the physical layer runs on FPGAs to ensure that all timing requirements can be met. Upper layers are run on x86 processors. The combination of processors gives the 5G NR Test UE the power to compute the processing intensive 5G NR standard in real time while maintaining flexibility.

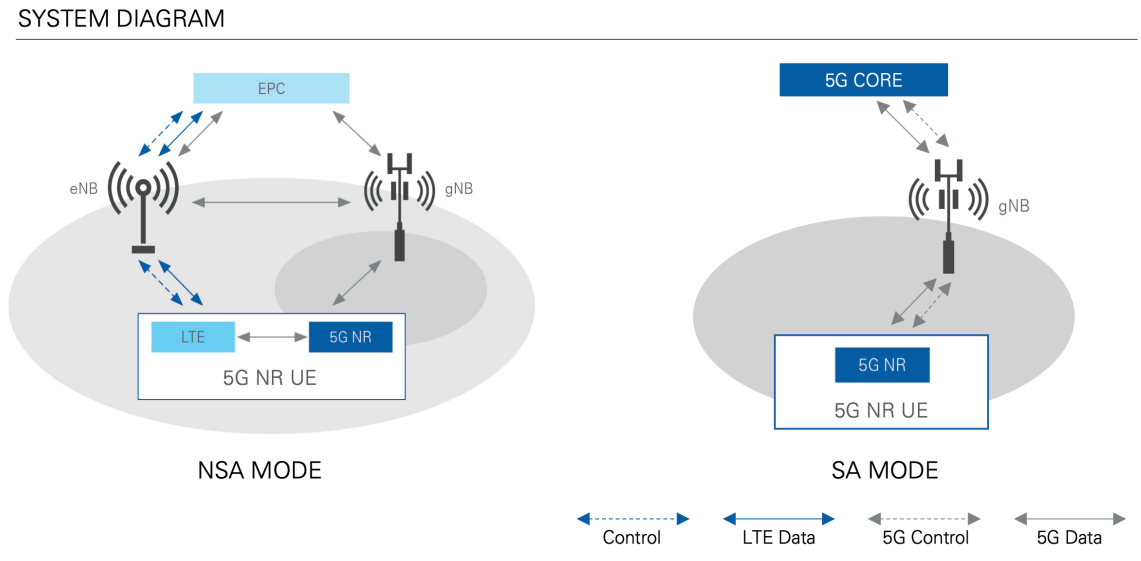

Figure 2: 5G NR NSA System Diagram (left) and 5G NR SA System Diagram (right)

About the NI 5G NR Test UE

Fully 3GPP release 15 compliant, the 5G NR Test UE emulates the full operation of end user device or user equipment (UE) and provides real-time status, performance and diagnostic information when connected to a gNodeB 5G NR capable system including micro cell, small cell and even macro cell base station components, subsystems or full equipment. The 5G NR Test UE can be configured for either NSA mode or SA mode (Note: NSA mode requires additional hardware for the LTE anchor that SA mode does not require). The ability to make an attach to 5G NR network equipment empowers users to evaluate performance, conformance to the standard, and interoperability. This is a critical step in evolving the 5G that is needed throughout the ecosystem from semiconductor, commercial infrastructure equipment, to service operators. The 5G NR Test UE can be used to test components, sub systems, and/or full base station or gNodeB equipment at every earmarked 5G band in the lab or in the field.

The 5G NR Test UE is built from a combination of PXI instrumentation and software defined radios (SDRs). This offers several key advantages. First, it allows users the flexibility to operate at in any sub 6 GHz band that is needed using the tunable RF front end in the SDRs. Second, since the entire system is software defined, as new features such as FFD mode become available, a software upgrade can deliver these new features and the same hardware can be reused.

Key Advantages

- Key performance metrics like throughput displayed in real time for analysis or debug
- Additional metrics logged for offline processing
- Software upgradeable

Standard Features

- Release 15 NSA or SA mode compliant software capable of completing a full attach
- 100 MHz bandwidth component carrier
- 4x2 MIMO configuration for 5G NR
- 2x2 MIMO LTE anchor for Option 3x
- User selectable center frequency between 500 MHz – 6 GHz
- Cabled or over-the-air functionality

Optional Features

- UE compliant RF transmit power for select NR and LTE bands (+23 dBm transmit)

Frequency Options

5G NR uses different carrier frequencies than previous generations of cellular communications, and NI's 5G New Radio Test UE is designed to accommodate this. Because this solution is based on SDRs, the center frequency can be selected by the end user from a range of supported frequencies. For UE compliant output power levels, an optional amplifier can be added to the configuration for select bands. The table below summarizes these options.

The key hardware component in the test UE that defines the test UE is built on the NI USRP RIO platform combined with an x86 server, FPGAs, clocking modules, and amplifiers. Additional information about these hardware components can be found below.

	Frequency	Component Carriers x Bandwidth	MIMO	Peak Throughput
Sub-6 NR	500 MHz-6 GHz*	1x100 MHz	4x4	2.3 Gbps
LTE	**Bands 1/2/3/5/7/11/13	1x20 MHz	2x2	100 Mbps

Table 2. Available frequencies and configurations information

* Below 500 MHz, only support for 80 MHz of instantaneous bandwidth. UE compliant power levels only available for 2 GHz – 6 GHz.

**Power amplifiers available for select bands. Other bands available for lab only. Additional bands for UE compliant power levels may be available by request

5G NR Test UE Software

There are two main software variants available for the 5G NR Test UE—one for NSA mode and one for SA mode. As mentioned above, for NSA mode, an additional radio is needed for the LTE anchor compared to the hardware needed to run the system in SA mode. This section will provide a software overview of both the NSA mode and the SA mode.

NSA Mode

The 5G NR Test UE software provides a full stack through the application layers of Release 15 non-stand-alone (NSA) mode UE with an LTE Release 15 anchor that is capable of interacting with other Release 15 standards compliant hardware. The software displays basic performance metrics and also collects data logs to allow for system level performance analysis.

Below is a functional block diagram of how the software operates. Support is available for 3x with an external data source/sink.

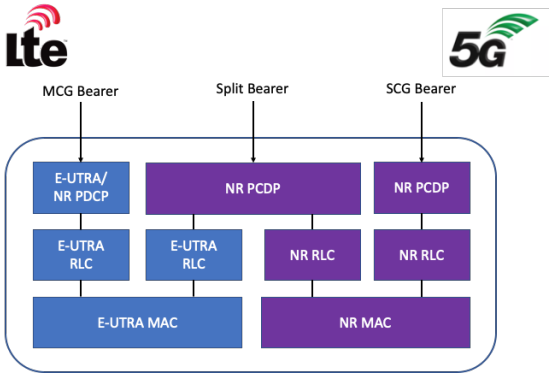

Figure 3: Test UE Protocol Stack for NSA Option 3x (Source: 3GPP TS 37.340)

As shown below in Figure 4, the physical layer is implemented on FPGAs. The lower MAC is also implemented in the FPGA. The L2 and above protocol stacks run on an x86 processor. The LTE anchor also runs on an x86 processor.

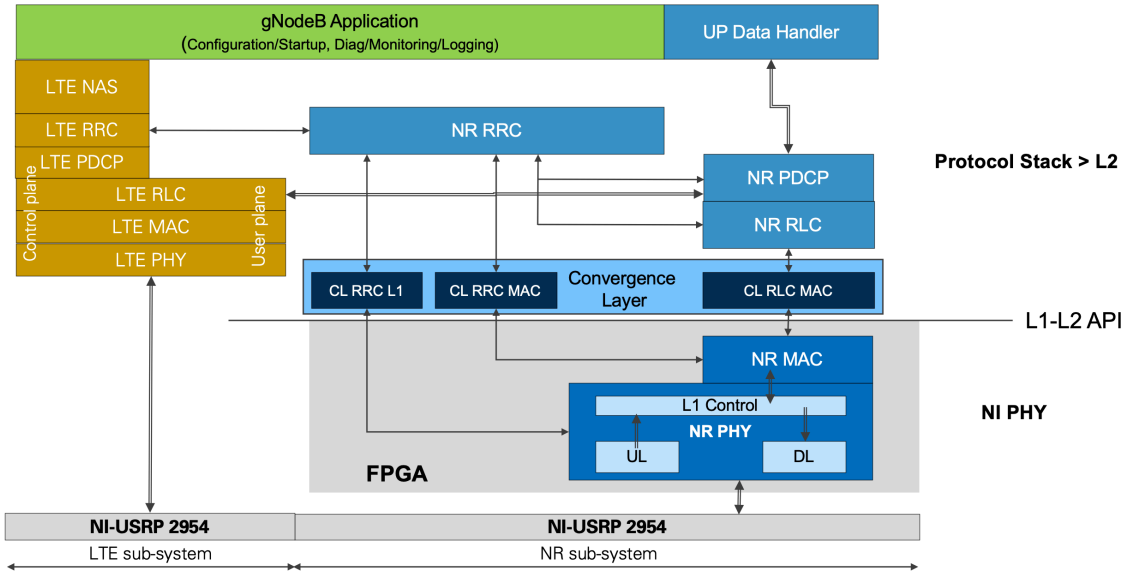

Figure 4: NSA Architecture

SA Mode

The overall software architecture for SA mode is the same as NSA. The LTE anchor is removed, and the LTE NAS is replaced with NR NAS. The USRP that was used for the LTE anchor is also removed from the system.

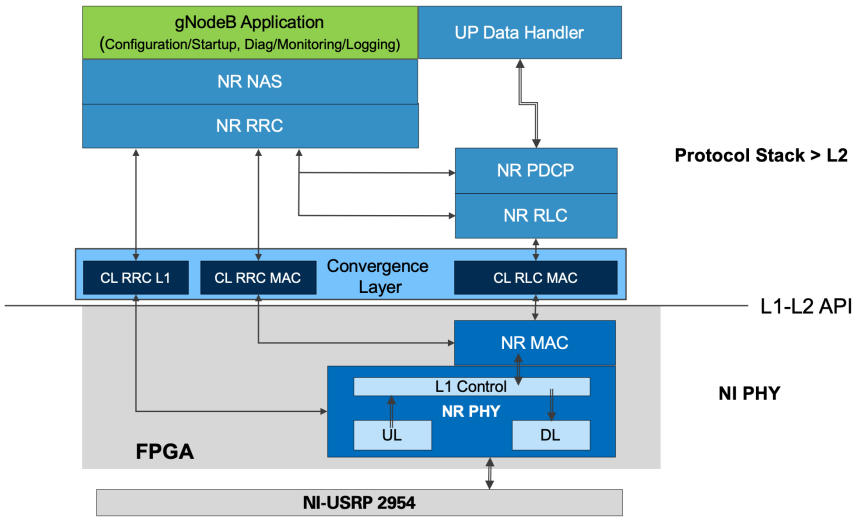

Figure 5: SA Architecture

Specification Overview

The NI 5G NR Test UE is 3GPP Release 15 compliant. The tables below provide more details about the L1, L2, and L3 parameters. More in depth datasheets are available upon request.

Parameter	Sub-6
3GPP Version	15.6*
Frequency	0.4-6 GHz
Operation	NSA and SA
Duplex mode	TDD / FDD
Carrier Bandwidth	Up to 100 MHz
No. of carriers	1
MIMO	4T4R with PDSCH: 4 Layers, PUSCH: 2 Layers
Subcarrier Spacing	15, 30 kHz
Modulation	OFDM: Up to 256 QAM
Peak throughput	2.3 Gbps
DL Channels/Signals	PDSCH, PDCCH, PBCH, PSS, SSS, DMRS, CSI-RS, TRS
UL Channels/Signals	PUSCH, PUCCH, PRACH, DMRS, SRS

*As of May 2020. Subject to change.

Table 1: L1 & RF Features

Error! Reference source not found. highlight the supported features for L2 and L3.

Layer	Supported Features
SDAP	QoS flow to DRB mapping
NAS	Registration/De-registration CM state handling
RRC	RRC Connection establishment/Reconfiguration/Release, Initial Security Activation, UE Capability Transfer, and DL/UL Information Transfer
	Measurement configuration and reporting
PDCP	Transfer of user and control plane data
	Duplicate Discarding
RLC	Acknowledged mode (AM), Unacknowledged Mode (UM), and Transparent Mode (TM)
	Segmentation/Reassembly/Reordering
MAC	HARQ/RA/SR procedures
	CE: Timing advance, PHR, BSR

Table 2: L2 and L3 Features

Software User Interface

Many different performance measurements for the test UE can be viewed from the front panel user interface (UI). The UI displays the received waveforms and performance information like uplink and downlink throughput. Additional monitoring and logging are available through a command line window.

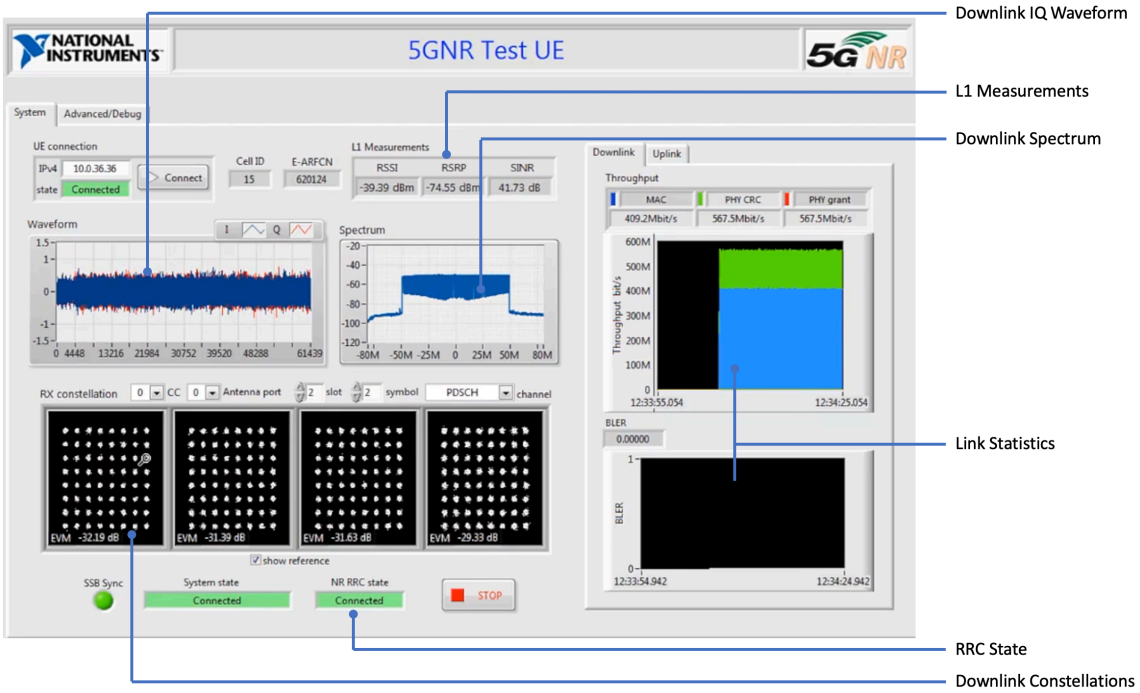

Figure 6: 5G NR Test UE Software UI

Diagnostic Monitor Logs

Logs are critical for debugging. Diagnostic Monitor (DM) logs record the data transactions between the UE and the handset over the RF interface. These logs can then be used for troubleshooting offline. Figure 7 shows an example of an L1 & MAC log and Figure 8 highlights portions of the log to demonstrate a UE going through the RACH procedure.

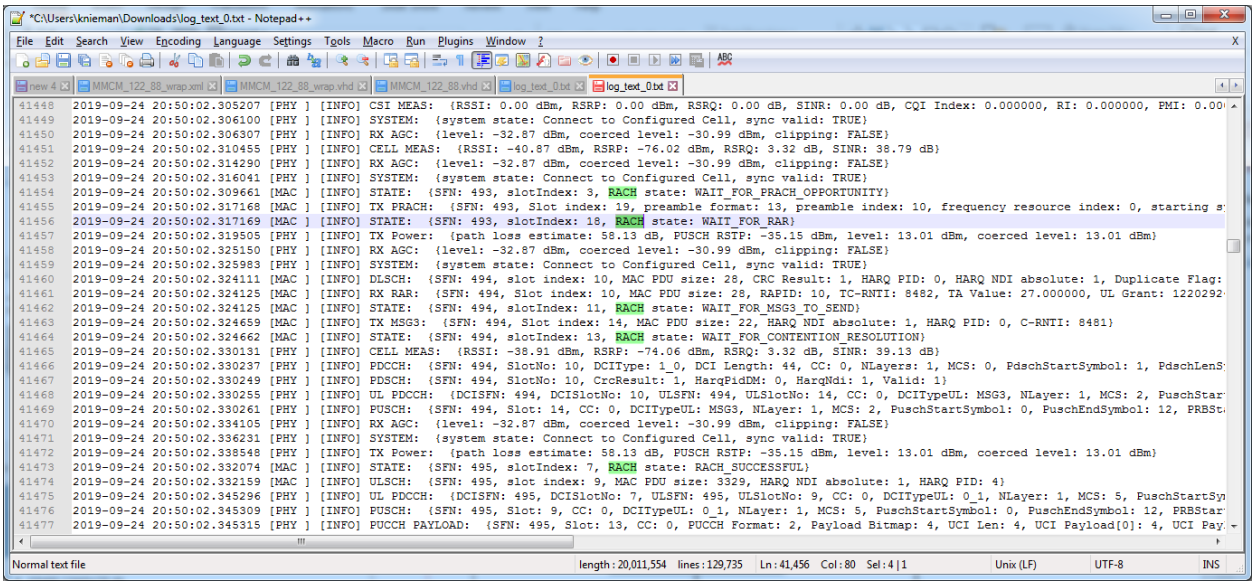

Figure 7: Excerpt for L1 & MAC Log File

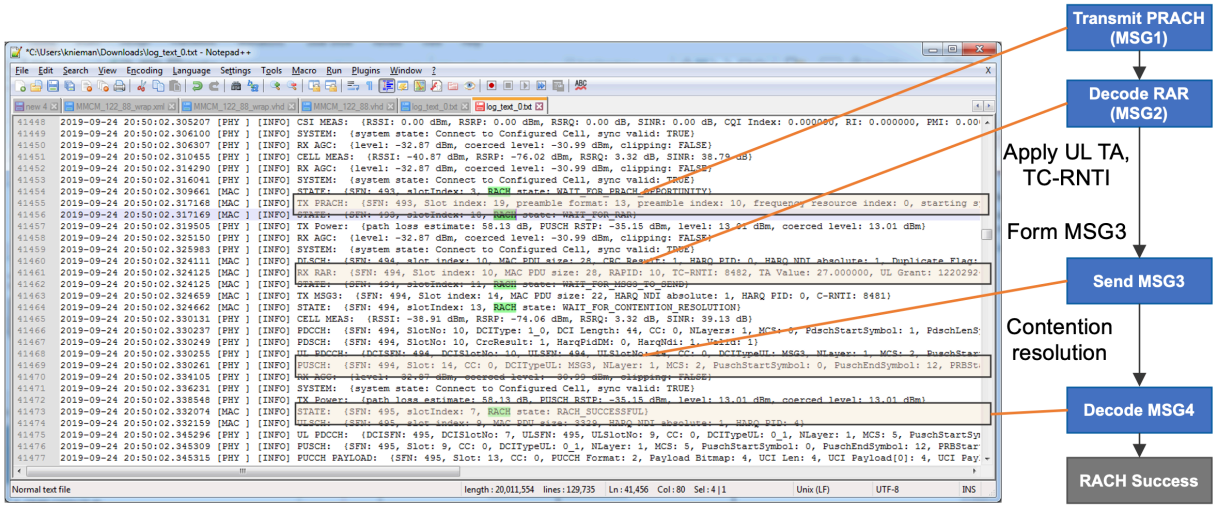

Figure 8: Annotated Log Showing RACH

Addition logs are available for the MAC layer, and for NSA mode an LTE log is also available. Logs can be customized by request to capture additional parameters if needed.

Hardware Services

All NI hardware includes a one-year warranty for basic repair coverage, and calibration in adherence to NI specifications prior to shipment. PXI systems also include basic assembly and a functional test. NI offers additional entitlements to improve uptime and lower maintenance costs with service programs for hardware. Learn more at ni.com/services/hardware.

	Standard	Premium	Description
Program Duration	1, 3, or 5 years	1, 3, or 5 years	Length of service program
Extended Repair Coverage	•	•	NI restores your device's functionality and includes firmware updates and factory calibration.
System Configuration, Assembly, and Test[1]	•	•	NI technicians assemble, install software in, and test your system per your custom configuration prior to shipment.
Advanced Replacement[2]		•	NI stocks replacement hardware that can be shipped immediately if a repair is needed.
System Return Material Authorization (RMA)[1]		•	NI accepts the delivery of fully assembled systems when performing repair services.
Calibration Plan (Optional)	Standard	Expedited[3]	NI performs the requested level of calibration at the specified calibration interval for the duration of the service program.

[1]This option is only available for PXI, CompactRIO, and CompactDAQ systems.
[2]This option is not available for all products in all countries. Contact your local NI sales engineer to confirm availability.
[3]Expedited calibration only includes traceable levels.

PremiumPlus Service Program

NI can customize the offerings listed above, or offer additional entitlements such as on-site calibration, custom sparing, and life-cycle services through a PremiumPlus Service Program. Contact your NI sales representative to learn more.

Technical Support

Every NI system includes a 30-day trial for phone and e-mail support from NI engineers, which can be extended through a Software Service Program (SSP) membership. NI has more than 400 support engineers available around the globe to provide local support in more than 30 languages. Additionally, take advantage of NI's award winning online resources and communities.