SOLUTION FLYER

5G New Radio Test UE Solution

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Solution Overview

5G New Radio Release 15 Non-Stand-Alone Mode 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.

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. 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.
About the NI 5G NR Test UE

Fully 3GPP release 15 non-stand-alone (NSA) 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 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 stand-alone (SA) 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 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 and 3a
- User selectable center frequency between 500 MHz – 6 GHz
- Cabled or over-the-air functionality

Optional Features

- UE compliant RF transmit power (+23 dBm transmit)
- Hard case for easy transportation (shown above)
5G NR Test UE Software

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 both Option 3a and 3x with an external data source/sink.

![Functional Block Diagram](image)

*Figure 3: 5G NR Test UE Functional Block Diagram*

The 5G NR standard has differences between its sub 6 GHz operations and above 6 GHz operations. The table below outlines the differences between the physical layer features for each variant.

<table>
<thead>
<tr>
<th>L1 and RF Specifications</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>500 MHz – 6 GHz (lab), 2 GHz – 6 GHz (field)</td>
</tr>
<tr>
<td>Operation</td>
<td>Non-stand-alone (NSA)</td>
</tr>
<tr>
<td>Duplex mode</td>
<td>TDD</td>
</tr>
<tr>
<td>Carrier Bandwidth</td>
<td>100 MHz</td>
</tr>
<tr>
<td>No. of carriers</td>
<td>1</td>
</tr>
<tr>
<td>MIMO</td>
<td>4x4 DL; 2x2 UL</td>
</tr>
<tr>
<td>Subcarrier Spacing</td>
<td>30 kHz (SSB and Data)</td>
</tr>
<tr>
<td>Modulation</td>
<td>OFDM: Up to 256 QAM</td>
</tr>
<tr>
<td>Peak throughput</td>
<td>2.3 Gbps</td>
</tr>
<tr>
<td>DL Channels/Signals</td>
<td>PDSCH, PDCCH, PBCH, PSS, SSS, DMRS, CSI-RS, PT-RS, TRS</td>
</tr>
<tr>
<td>UL Channels/Signals</td>
<td>PUSCH, PUCCH, PRACH, DMRS, PT-RS, SRS</td>
</tr>
</tbody>
</table>

*Table 1: L1 Features*
Table 2 and Table 3 highlight the supported features for L2 and L3.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Supported Features</th>
<th>Layer</th>
<th>Supported Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>RLC</td>
<td>Unacknowledged Mode (UM) only</td>
<td>RRC</td>
<td>4G-5G Inter-RAT (Addition/Release)</td>
</tr>
<tr>
<td></td>
<td>Segmentation/Reassembly/Reordering</td>
<td></td>
<td>Measurement configuration and reporting</td>
</tr>
<tr>
<td>MAC</td>
<td>HARQ/RA/SR procedures</td>
<td>PDCC</td>
<td>Transfer of user and control plane data</td>
</tr>
<tr>
<td></td>
<td>CE: Timing advance, Scell Activation/Deactivation, PHR, BSR</td>
<td></td>
<td>Duplicate Discarding</td>
</tr>
<tr>
<td></td>
<td>Beam Management (Above-6 only)</td>
<td></td>
<td>Split bearer routing (DRB only)</td>
</tr>
</tbody>
</table>

Table 2: L2 Features

Table 3: L3 Features

Software User Interface

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

Figure 4: 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. Here is an example of a real DM log created using the 5G NR Test UE.

![Example DM Log](image)

Figure 5: DM Log File Excerpt from the 5G NR Test UE
Hardware Components

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 system 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.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Component Carriers x Bandwidth</th>
<th>MIMO</th>
<th>Peak Throughput</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sub-6 NR</td>
<td>500 MHz-6 GHz* 1x100 MHz</td>
<td>4x4</td>
<td>2.3 Gbps</td>
</tr>
<tr>
<td>LTE</td>
<td>**Bands 3/5/7/11/41 1x20 MHz  **</td>
<td>2x2</td>
<td>100 Mbps</td>
</tr>
</tbody>
</table>

Table 2. Available frequencies and configurations information

* 2 GHz – 6GHz for field
**Power amplifiers available for select bands. Other bands available for lab only. Additional bands for UE compliant power levels may be available by request

NI Universal Software Radio Peripheral (USRP)

NI USRPs are SDRs that combine a flexible RF front end with a user-programmable FPGA. The test UE is built on the NI-USRP 2954 which also includes a GPSDO for improved signal quality.

![Figure 4. USRP-2954](image)

- **Frequency Range**: 500 MHz* to 6 GHz
- **Maximum Bandwidth**: 100 MHz*
- **Analog RF Channels**: 2
- **Onboard Clock**: OXCO GPSDO
- **Output power**: Up to 23 dBm**

*Specifications shown are 5G NR test UE system-level specifications, even though the NI USRP 2955 might have different specifications when used outside the test UE

**When used with optional RF conditioning modules

FlexRIO FPGA Modules

The NI FlexRIO modules are used in the test UE as FPGA computational engines. The entire 5G NR physical layer, written in LabVIEW FPGA, runs on these modules to process all of the data for uplink and downlink in real time. Two different models are used, the PXIe-7902 and the PXIe-7915.

<table>
<thead>
<tr>
<th>Model</th>
<th>FPGA</th>
<th>PCIe</th>
<th>Aux I/O</th>
</tr>
</thead>
<tbody>
<tr>
<td>PXIe-7902</td>
<td>Virtex 7 485T</td>
<td>Gen 3 x8</td>
<td>24 TX, 24 RX serial lanes</td>
</tr>
<tr>
<td>PXIe-7915</td>
<td>Kintex UltraScale KU060</td>
<td>Gen 3 x8</td>
<td>GPIO, 4 HSS</td>
</tr>
</tbody>
</table>
## 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](http://ni.com/services/hardware).

<table>
<thead>
<tr>
<th>Program Duration</th>
<th>Standard</th>
<th>Premium</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of service program</td>
<td>1, 3, or 5 years</td>
<td>1, 3, or 5 years</td>
<td></td>
</tr>
</tbody>
</table>

**Extended Repair Coverage**
- NI restores your device’s functionality and includes firmware updates and factory calibration.

**System Configuration, Assembly, and Test**
- NI technicians assemble, install software in, and test your system per your custom configuration prior to shipment.

**Advanced Replacement**
- NI stocks replacement hardware that can be shipped immediately if a repair is needed.

**System Return Material Authorization (RMA)**
- NI accepts the delivery of fully assembled systems when performing repair services.

**Calibration Plan (Optional)**
- Standard
- Expedited
- 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](http://ni.com) and [communities](http://ni.com/community).