Four Tips for 5G New Radio Signal Analysis
Overview

Strong demand for faster-data-rate applications has triggered the need for technologies capable of wide signal bandwidth operating at higher frequencies. 5G New Radio (NR) operates in two frequency ranges (FR): FR1 for sub-6 GHz frequencies and FR2 for millimeter-wave (mmWave) frequencies. Maximum channel bandwidth increases to 100 MHz for FR1 and 400 MHz for FR2, as shown in Table 1. The higher frequencies and wider bandwidths for 5G NR bring in new design and test challenges.

Table 1. 3GPP frequency ranges, bands, and maximum channel bandwidth

<table>
<thead>
<tr>
<th>Frequency band</th>
<th>Frequency range</th>
<th>Maximum channel bandwidth</th>
</tr>
</thead>
<tbody>
<tr>
<td>FR1</td>
<td>1 to 255</td>
<td>410 MHz to 7.125 GHz</td>
</tr>
<tr>
<td>FR2</td>
<td>257 to 511</td>
<td>24.25 GHz to 52.6 GHz</td>
</tr>
</tbody>
</table>

At mmWave frequencies, the components are compact and highly integrated with no place to probe, resulting in the need for radiated tests, also known as over-the-air tests. The excessive path loss between instruments and devices under test (DUTs) results in a lower signal-to-noise ratio (SNR) making signal analysis measurement challenging. The low SNR degrades transmitter measurements such as error vector magnitude (EVM) and adjacent channel leakage ratio (ACLR), which do not represent the actual performance of the DUTs. Even worse, analyzing wide-bandwidth signals at mmWave requires overcoming the impacts of frequency responses that also degrade signal quality.

5G NR requires you to think differently about how you design and test devices. Here are four tips to help you successfully analyze 5G NR signals and get your designs to market faster.
Tip 1: Apply Channel Corrections to Remove Frequency Responses

A signal analyzer provides an internal calibration routine to correct its frequency responses, including amplitude and phase responses. When you are building a test system, cables, connectors, switches, and fixtures in the paths between the signal analyzer and the DUT can degrade measurement accuracy because of flatness errors. The frequency responses get worse when you test 5G NR FR2 signals with wider bandwidths and higher frequencies. You need to extend the measurement accuracy from the signal analyzer’s input port (reference plane) to the DUT’s test port (test plane), as shown in Figure 1.

![Diagram](image_url)

Figure 1. Consider the test network elements for channel correction

Signal analyzers allow you to configure amplitude corrections and complex corrections, which include both amplitude and phase corrections, to correct frequency responses. For amplitude corrections, you can measure the amplitude frequency responses of the test network using a signal generator plus a power meter and sensor, then input the correction values to the signal analyzer. For complex corrections, you can make frequency response measurements of the test network using a vector network analyzer and save the measurement results in the .s2p format. Keysight PathWave X-Series Applications software allows you to load the .s2p file and correct amplitude and phase frequency responses. Keysight PathWave vector signal analysis (VSA) software allows a user to control corrections to compensate for external devices connected to the signal analyzer, including attenuators, amplifiers, radio-frequency (RF) filters, mixers, and IF filters, as shown in Figure 2.
Figure 2. User corrections to compensate for external device errors

**Tip 2: Simplify Measurement Setup for 5G NR Signal**

The 3rd Generation Partnership Project (3GPP) specifies 5G NR test requirements for user equipment (UE) and base stations (gNB). Table 2 illustrates the technical specification (TS) for UE and gNB minimum test requirements and conformance tests. The conformance testing documents specify the measurement procedures. The testing method consists of conducted tests, radiated tests, or a hybrid for the various frequency ranges.
### Table 2. 3GPP technical specification for 5G NR test

<table>
<thead>
<tr>
<th>Device</th>
<th>Minimum requirements</th>
<th>Conformance tests</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>UE</td>
<td>TS 38.101</td>
<td>Conducted tests</td>
<td>FR1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Radiated tests</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Conducted / radiated</td>
<td></td>
</tr>
<tr>
<td>gNB</td>
<td>TS 38.104</td>
<td>Conducted tests</td>
<td>FR1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Radiated tests</td>
<td>FR1 and FR2</td>
</tr>
</tbody>
</table>

Each document specifies the transmitter characteristics, receiver characteristics, and performance test requirements. Additionally, Part 1 represents conducted tests, and Part 2 represents radiated tests. Part 3 is for NR UE interworking between FR1 and FR2, or NR and LTE.

### Configure measurement setup for 5G NR components test

Stimulus-response measurements provide a straightforward method for evaluating the performance of RF components. They require a stimulus input test signal and acquisition of the output signal for further analysis. Figure 3 shows a signal generator (bottom) and a signal analyzer (top) setup for stimulus-response measurements.

![Stimulus-response measurement setup](image-url)

*Figure 3. Stimulus-response measurement setup*
To configure 5G NR test signals on the signal generator, you can use waveform-creation tools such as Keysight PathWave Signal Generation for 5G NR. You can save the configuration as a PathWave 89600 VSA setup file, simplifying VSA configuration to quickly demodulate the signal without configuring the demodulation parameters on a signal analyzer. Keysight’s new M9384B VXG signal generator allows you to automatically set up the X-Series signal analyzer to measure the desired signal from the signal generator by pressing a single button.

**Set up 5G NR standard-compliant parameters**

To perform conformance tests, 3GPP identifies test signals for specific test cases. 3GPP defines the test models (TM) for 5G NR gNB transmitter test cases and the fixed reference channel for receiver test cases in TS 38.141. The test models standardize the resource block allocations. For example, TM3.3 is for the transmitter test cases, frequency error, and modulation quality.

The physical channels set up for tests need to be based on the specification, including logical channels, resource allocation, payload data, bandwidth parts, control resource sets, cell-specific settings, and RF parameters. Each test signal has more than 50 adjustable parameters with relevant bandwidths and numerologies (subcarrier spacing). Figure 4 shows that the measurement application supporting defined, standard-based conformance test setups can save time and give you confidence that your measurements comply with standards.

![Figure 4. 5G NR downlink signal demodulation setups](image)
Tip 3: Optimize EVM Measurements

The structure of a signal analyzer is similar to an RF receiver. Figure 5 is a simplified block diagram of a vector signal analyzer. When making EVM measurements, you need to set optimum levels for the signal analyzer’s input mixer, the phase noise configuration of the local oscillator (LO), and the digitizer to achieve the best results.

![Figure 5. A block diagram of a signal analyzer](image)

**Optimize mixer level**

Keysight signal analyzers allow you to adjust attenuation for minimum clipping to protect against input signal overloads. This function accelerates setting the input attenuation but does not necessarily optimize measurement dynamic range. You need to fine-tune the attenuation manually to achieve the best measurement results.

**Optimize SNR for an IF digitizer**

The 5G NR standard specifies the maximum channel bandwidth at 400 MHz for FR2. However, wider bandwidths also gather more noise. Wideband noise and excess path loss at millimeter frequencies between instruments and DUTs result in a lower SNR for the digitizer of the signal analyzer. The low SNR causes a poor EVM measurement result, which does not represent the performance of the DUT.

The system intermediate frequency (IF) noise of a signal analyzer must be low enough and the input signal to the digitizer must be high enough without overloading the digitizer to maximize SNR for EVM measurements. This requires a combination setup of RF attenuators, preamplifier, and IF gain value based on the measured signal peak level.
Keysight X-Series signal analyzers let you press a single key to optimize these hardware settings, improving SNR and avoiding digitizer overload, as shown in Figure 6. The optimization processing requires measuring the signal peak level and setting up the analyzer. However, the measured period may not represent the complete power characteristics of the input signal. You can manually tweak the settings, such as IF gain and RF attenuators, to achieve the best measurement results.

![Figure 6. Optimizing EVM measurements for 5G NR modulation analysis](image)

**Use full bypass path**

Signal analyzers provide several RF signal paths — such as default path, microwave preselector bypass, low-noise path, and full-bypass path — to lower noise, improve sensitivity, and reduce signal path loss for a better SNR. The full-bypass path, which combines the low-noise path with the microwave preselector bypass path. This RF path avoids multiple switches in the low-band switch circuitry and bypasses the microwave preselector. At millimeter-wave frequencies, the full-bypass path has up to 10 dB less loss than the default path and improves SNR for better EVM measurements.

To learn more about improving wideband signal analysis, download the application note [Full Bypass Path for X-Series Signal Analyzers](#).
Optimize phase noise for wideband applications

Phase noise describes the frequency stability of an oscillator. It is the noise spectrum around the oscillator’s signal in the frequency domain. Phase noise can cause errors in the phase component of an error vector. The phase noise performance of a signal analyzer contributes error to EVM measurements.

Why is the phase noise critical to 5G measurements? 5G NR adopts the orthogonal frequency-division multiplexing (OFDM) modulation scheme, which uses many closely spaced orthogonal subcarrier signals, each with its own modulation scheme, to transmit data in parallel. During frequency conversion with a poor phase noise LO of a signal analyzer, the subcarrier with phase noise spreads into other subcarriers as interference, as shown in Figure 7. The interference degrades modulation quality.

Figure 7. The impact on OFDM subcarriers from poor phase noise LO of a signal analyzer
Tip 4: Optimize ACLR Measurements

The Adjacent Channel Leakage Ratio (ACLR) is a key characteristic in the 3GPP transmitter conformance tests for base station and user equipment. ACLR examines spectral regrowth that spreads outside the main channel. It measures the ratio of the main channel power to the power that falls into adjacent channels, as shown in Figure 8.

![Figure 8. The spectral regrowth (red) of a digital modulation signal](image)

To perform 5G NR ACLR measurement, you need to optimize a signal analyzer’s dynamic range to obtain the true performance of the DUT. Here are four practices to improve the ACLR measurement results:

1. **Optimize the signal level at the mixer**

To optimize the signal level at the input mixer, you can adjust the attenuator of the signal analyzer for minimal clipping. The X-Series signal analyzer automatically selects an attenuation value based on the current measured signal value. This automated technique provides a good starting point for achieving the optimal measurement range. Then you can fine-tune the attenuation manually to achieve the best measurement results.
2. Change the resolution bandwidth filter

The resolution bandwidth (RBW) filter is a bandpass filter in the IF path of a signal analyzer. Using a narrow RBW lowers the displayed average noise level of the spectrum analyzer, increasing the dynamic range and improving the sensitivity of the spectrum analyzer. However, the lower RBW causes a longer sweep time.

3. Turn on noise correction or NFE

Both noise correction and noise floor extensions (NFEs) compensate for a signal analyzer noise floor, but the measurement results are slightly different. When you enable noise correction, the signal analyzer measures its noise power and subtracts the noise from the measurement result. NFE uses a model of the analyzer noise floor, adapted to the current conditions, such as center frequency, RBW, and ambient temperature. The parameters of this model are determined in the factory or field in a highly averaged measurement. The analyzer does not need to make an additional measurement on its noise floor.

The advantage of noise correction is that it uses the latest correction data at the current ambient and exact center frequency, so it has slightly better measurement accuracy than NFE. Both noise correction and NFE improve ACLR measurements by up to 5 dB. To learn more about NFE, download the application note Using Noise Floor Extension in an X-Series Signal Analyzer.

4. Change the measurement methods

Measuring ACLR channel power has three approaches, including include integration bandwidth (IBW), filtered IBW, and RBW:

- **IBW**: A signal analyzer makes a single sweep and computes the band power of each offset with the sweep trace.
- **Filter IBW**: Filter IBW uses a sharp, steep cutoff filter to improve dynamic range. This technique does degrade the absolute accuracy of the power measurement result, but it does not degrade the relative power accuracy.
- **RBW**: The RBW method uses zero-span and an appropriate RBW setting to capture all the power in the carrier channel and adjacent channels. This approach is slower than the IBW method but improves repeatability.

By using these practices in combination, you can optimize the ACLR measurement to improve dynamic range, test speed, and repeatability.
Summary

Increased network traffic resulting from rapidly evolving cellular communications systems creates greater demand for wider bandwidths and higher operating frequencies to support next-generation wireless standards. You face test challenges such as frequency responses, excessive path loss, and lower SNR for accurate transmitter measurements. To address these challenges, you need to correct the effects of the response and optimize the signal analyzer to improve measurement integrity.

Keysight provides products and solutions to simplify and optimize 5G NR measurement setups to keep up with 5G NR's accelerating pace and complexity. Our portfolio of 5G NR solutions provides the tools to address these challenges, with solutions to emulate, measure, and validate 5G NR RF and protocol signals so you can innovate, transform, and win in 5G.

To see your device’s true behavior, use superior phase noise performance signal analyzers with enough analysis bandwidth for modulation analysis. Do not let the phase noise of the signal analyzer bottleneck your measurements results.

Table 3. Keysight 5G NR waveform generation and analysis solutions — software

<table>
<thead>
<tr>
<th>Application software</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N7631APPC / N7631EMBC</td>
<td>PathWave Signal Generation for 5G NR</td>
</tr>
<tr>
<td>N7630APPC / N7630EMBC</td>
<td>PathWave Signal Generation for Pre-5G</td>
</tr>
<tr>
<td>N7608APPC / N7608EMBC</td>
<td>PathWave Signal Generation for Custom OFDM</td>
</tr>
<tr>
<td>N9085EM0E</td>
<td>5G NR Measurement Application</td>
</tr>
<tr>
<td>N9054EM1E</td>
<td>Vector Modulation Analysis Custom OFDM Application</td>
</tr>
<tr>
<td>89601BHNC</td>
<td>5G NR modulation analysis</td>
</tr>
</tbody>
</table>
## Table 4. Keysight 5G NR waveform generation and analysis solutions — hardware

<table>
<thead>
<tr>
<th></th>
<th>Signal Analyzer</th>
<th>Signal Generator</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UXA</td>
<td>PXA</td>
</tr>
<tr>
<td></td>
<td>N9042B</td>
<td>N9041B</td>
</tr>
<tr>
<td>Max. frequency</td>
<td>110 GHz</td>
<td>110 GHz</td>
</tr>
<tr>
<td>Max. bandwidth</td>
<td>4 GHz</td>
<td>1 GHz</td>
</tr>
<tr>
<td></td>
<td>(9.6 GHz²)</td>
<td>(1 GHz²)</td>
</tr>
<tr>
<td>Phase noise at 10 GHz, 10 kHz offset</td>
<td>-126 dBc/Hz</td>
<td>-126 dBc/Hz</td>
</tr>
</tbody>
</table>

1. Support maximum analysis bandwidth with wide IF output option and an external digitizer.
2. Get up to 4 GHz of RF bandwidth with wideband external differential I/Q inputs.
3. Get up to 4 GHz of RF bandwidth with dual-channel bonding.
4. Modular form factor.

## Reference

- 4 Tips for 5G New Radio Signal Creation
- Three Best Practices for Optimizing EVM Measurements for Wideband Signals
- Using Noise Floor Extension in an X-Series Signal Analyzer