Application Note

Anritsu Advancing beyond

# 5GNR Base Station Measurements in the Field

## Changes in Cellular Base Station Deployment Testing

The first commercial 5GNR networks compliant to the 3GPP specifications started to be deployed in 2019. 5G technology offers the prospect of superior network performance to smartphone users and opens new application opportunities in business. New markets for 5G includes the use of massive IoT sensor density in homes and smart factories and improved autonomous driving.

Many new 5G networks comply with the “Non-standalone” network architecture where the network is supported by the existing LTE infrastructure. As a result, when deploying a new 5G network, it is often necessary to also validate the performance and coverage of the existing LTE base stations.

Network operators who have historically built previous generation cellular networks, including GSM, 3G (WCDMA), and LTE have years of experience in testing new base station installations. Typically, the base station radio has been tested by connecting a signal analyzer to an RF test port on the transmitter and performing transmitter and modulation quality measurements. If the radio transmitter and antenna are connected with RF cable feeds, the performance of these components must also be validated.

Many 5G base stations, often referred to as gNB, have a very different physical construction from an LTE base station. New antenna technologies to facilitate beam steering have been developed using active antenna systems with multiple active elements. These antennas integrate RF amplifiers and phase shifters behind each element. The result is that many 5G base stations do not provide an RF test port to facilitate traditional base station measurements. This has led away from direct measurements at a test port towards over-the-air (OTA) measurements that are performed many meters in front of the antenna showing a change in the installation test philosophy.

## Common 5G Base Station RF Measurements

The radio layer measurements on 5G base stations can broadly be categorized as transmitter quality and demodulation based measurements.

Transmitter quality measurements include:

- Channel Power
- Adjacent Channel Power
- Occupied Bandwidth
- Spectral Emission Mask
- Equivalent Isotropic Radiated Power

These measurements are used to confirm that any transmitter is compliant to national regulatory requirements to prevent interference with other legitimate users of the spectrum. They essentially test to ensure that the transmitter is not generating any signals outside its licensed spectrum and that it is not transmitting more power than its license allows. Each country regulates the use of the RF spectrum, often charging millions of dollars for access. It is important that any user does not interfere with those users in the adjacent spectrum and that the transmitter is not generating harmonic or spurious emissions that interfere with users in other parts of the spectrum.

Demodulation based measurements include:

- Base Station Identification (Display of gNB PCI)
- Frequency Error
- Time Offset
- SSB Beam Identification
- Sync Signal RSRP/RSRQ/SINR
- Modulation Quality (EVM)

In addition to transmitter and modulation quality measurements, it is often necessary to perform insertion and return loss measurements on the RF cables and antennas. When the base station installation is completed, a coverage mapping drive is also common to validate that good signal coverage is provided in the local area.

National regulators are especially interested in transmitter quality measurements to fulfill their role of protecting the licensed spectrum. Base station installers may also perform basic beam analysis on a 5G signal to validate the PCI and beams are configured as required. If the base stations have separate radios and antennas with cable feeds between them, line sweep measurements on the feed are also required.

Subsequent to the base station going live, many operators have network optimization teams whose responsibility is to track down reasons for poor network performance as a result of changes to the environment such as new interfering signals or transmitter performance degradation.

*Temporary Base Station Installations at Festivals or Large Sporting Events Require Field Portable Instruments to Verify Performance and Ensure There is no Interference with Permanent Networks and Verify Coverage*

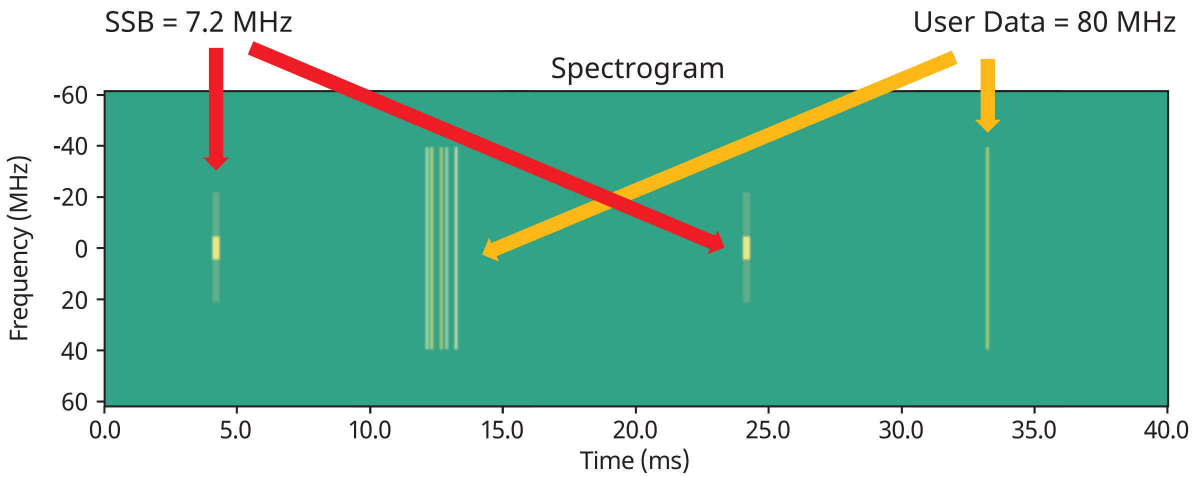
## Instrument Requirements

The move towards OTA measurements requires a field portable battery powered instrument that supports standard transmitter measurements and also includes a 5G/LTE signal analyzer mode for the demodulation measurements.

5G demodulation measurements are performed on the synchronization signal block (SSB). The SSB is a defined signal transmitted periodically in the 5G frames, where the exact periodicity is dependent on the subcarrier spacing and case type. The SSB bandwidth depends on the subcarrier spacing and whether the 5G radio is in the FR1 band (nominally sub 6 GHz) or the FR2 band (6 to 40 GHz).

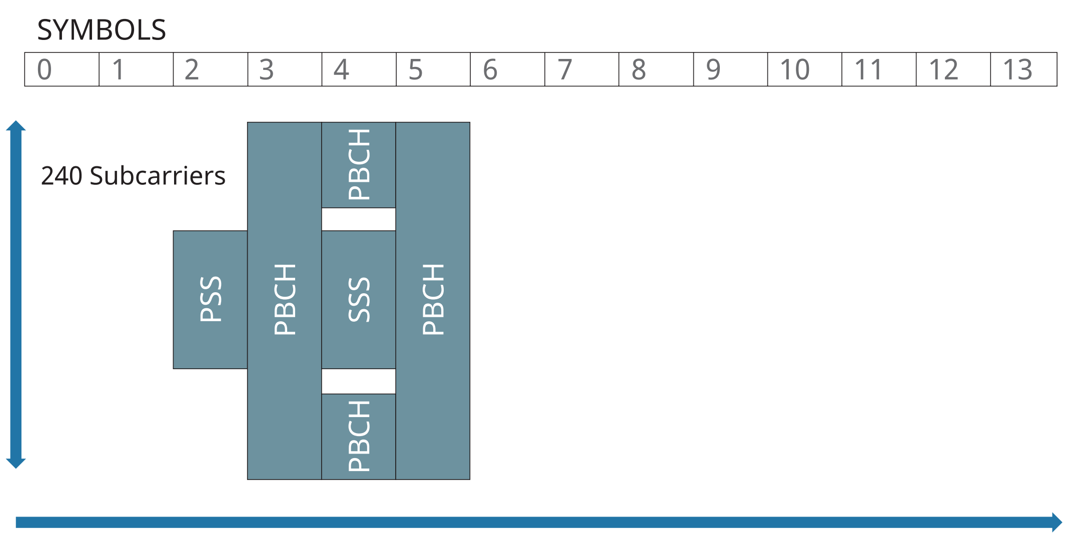
| Frequency | SCS | # Subcarriers | SSB Bandwidth |
|---|---|---|---|
| FR1 | 15 kHz | 240 | 3.6 MHz |
| | 30 kHz | 240 | 7.2 MHz |
| FR2 | 120 kHz | 240 | 28.8 MHz |
| | 240 kHz | 240 | 57.6 MHz |

*For FR1 Radios, the Maximum Required Analysis Bandwidth is 7.2 MHz*

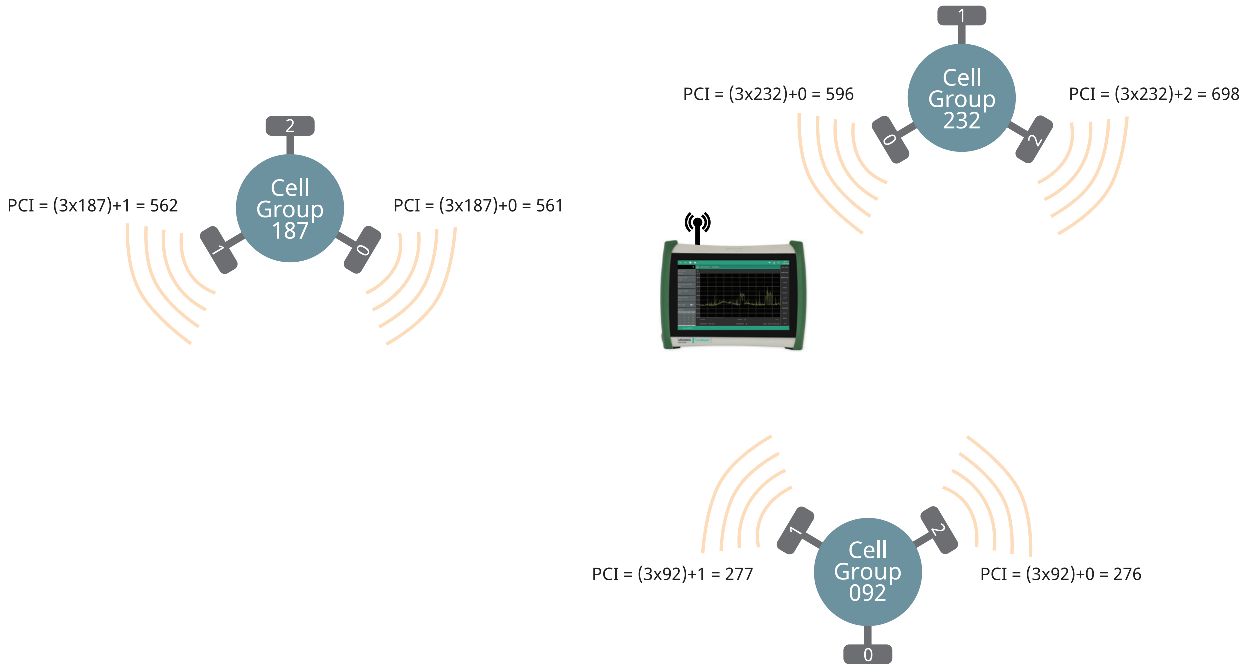



*A 40 ms Spectrogram Capturing Four 5G Frames (10 ms each). The Signal Captured OTA has 100 MHz Bandwidth. Two SSB Blocks with 7.2 MHz Bandwidth and Zero Frequency Offset are Clearly Identified Every Second Frame*

When the instrument is connected by an RF cable to a test port on the base station, then the instrument will only see the output of a single base station resulting in a single physical cell identification (PCI). When testing OTA, it is very likely that multiple base station signals are received simultaneously at the instrument receiver, which is the reason why multiple PCIs need to be decoded. In 5GNR SUMMARY mode, the Field Master MS2080A measurement decoding is configured for a direct connection or when only one base station is seen OTA, for example if using a directional antenna. When multiple base stations are seen at the Field Master MS2080A input, OTA (Multi PCI) mode on the Field Master MS2080A is the preferred setting as additional signal processing is performed to display results for all visible base stations on a single results screen.



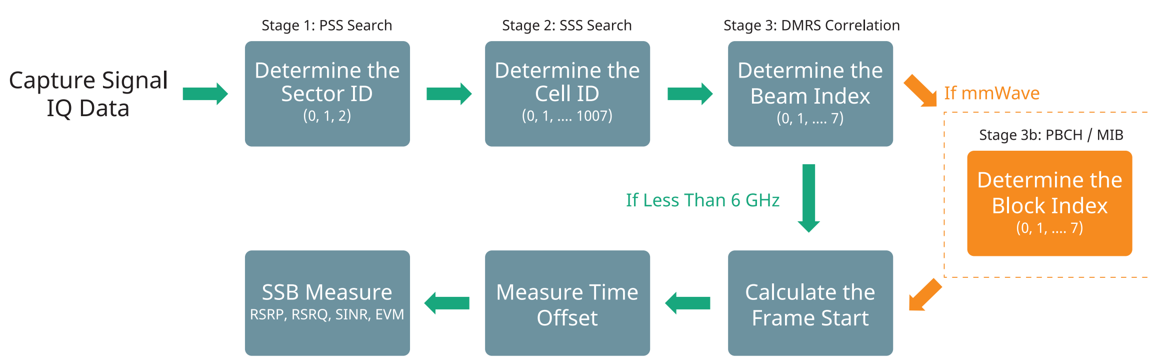

*The SSB Always Has the Same Structure as Shown Above, 4 Symbols Long and 240 Subcarriers Wide. The Number and Position of SSBs in a 5G Frame Depends on the Case Implementation. For FR1 Transmissions, There Can be Up to 8 SSBs in a Frame*




*When Used in OTA Multi PCI Mode, the Field Master MS2080A Decodes Modulation Quality Results from all Base Stations within Range*

In 5GNR SUMMARY mode, the user must enter the SSB offset at the start of the measurement process to within a nominal frequency tolerance of 8 to 10 subcarriers. This can be entered manually, or if unknown, the Field Master MS2080A SSB Auto Detect feature should be used. In the case of a direct connection the essential stages of the decoding and measurements are:

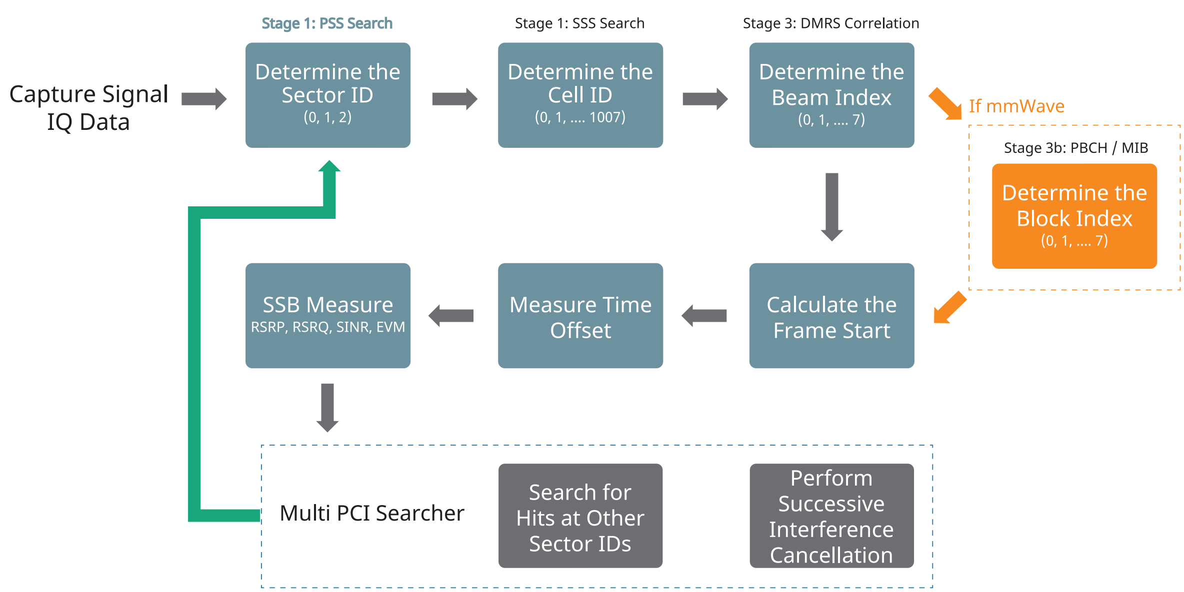
1. PSS search and coarse frequency offset estimation. The sector ID is obtained at the end. At this stage the signal processing has a rough approximation of the SSB center frequency.
2. Frequency offset correction, OFDM demodulation to extract the SS block and then SSS search to obtain the cell group ID. The strongest PSS and SSS sequences combine to give the primary cell ID.
3. PBCH DM-RS correlation to obtain the beam index.
   Note: For FR2 base stations, PBCH/MIB decoding in the 120 kHz/240 kHz SCS case obtains the block time index.
4. Frame start calculation from the location of the detected SSB and OFDM frame demodulation.
5. Time offset measurement from the frame start relative to the GPS time reference (1 second timing pulse).
6. SSB Radio Resource Management (RRM) measurements: RSRP, RSSI, RSRQ, SINR at every potential beam location.




*Basic Decoding Process for a Direct Connection to a 5G Base Station*

The figure below shows the process for making an OTA 5G Base Station measurement using successive iterations. Following decoding of the first PCI detected (steps 1 through 6 described above for direct connect measurements), the instrument then searches further for other cells. This is accomplished by performing successive interference cancellation of the previously detected cells and looking for other active sector IDs. The process is repeated at every possible beam location for the selected sub carrier spacing (SCS) to locate additional sector IDs. The output from this process is modulation quality and beam index measurements for all PCI incidents on the instrument input port. The process of successive interference cancellation also results in the detection of signals at a lower power level.

## Lower Power Threshold for OTA Testing

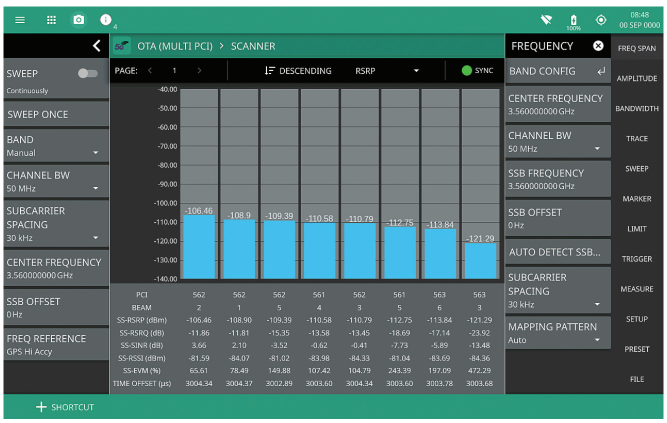


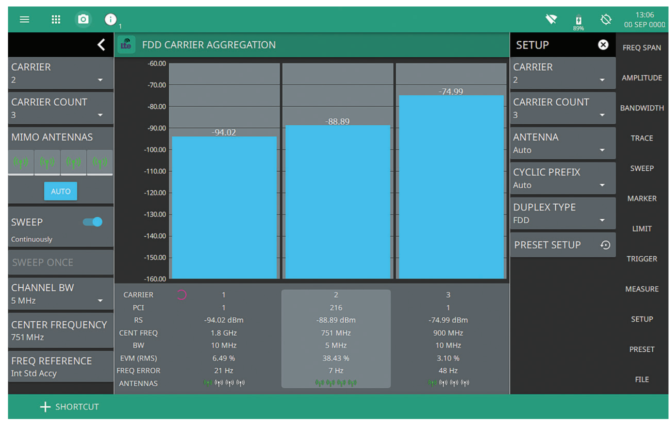

*Enhanced Decoding Process for OTA Measurements*

## 5G Measurements with the Field Master MS2080A

Anritsu's Field Master MS2080A is designed to perform all the RF measurements commonly required by regulators and network operators installing and maintaining 5G base stations. Its light weight and battery operation make it ideal for field use. The user interface is a high resolution multi touch screen with user selectable color themes to enable operation in direct sunlight and for use at night in low level light conditions.

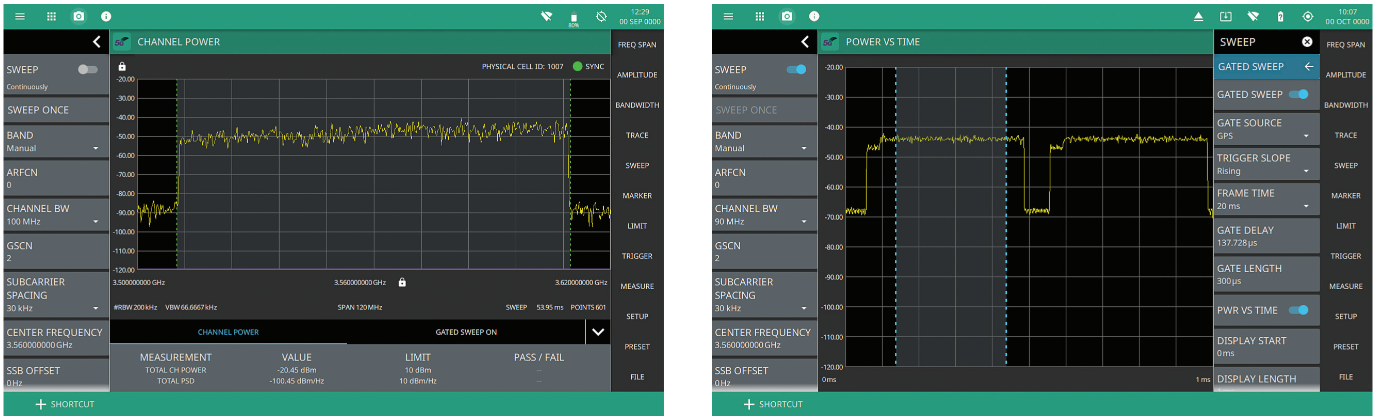
From the 5G measurement mode, select between a direct connection (5GNR SUMMARY) to the base station or OTA (Multi PCI) mode. Configure the channel frequency, SSB offset, channel bandwidth, and subcarrier spacing according to the condition of the gNB under test and Field Master MS2080A synchronizes to the signal and displays results from the decoded SSB. Where operators have implemented a carrier aggregation network to enhance capacity, the results from multiple different frequency 5G signals are available in CARRIER AGGREGATION mode. Up to eight frequencies are supported with all results displayed on a single screen.






*5G Multi PCI OTA Results (Left) and OTA Results for LTE Carrier Aggregation (Right)*

To confirm that the transmitted 5G signal is not spreading into adjacent channels and causing interference, measurements of Occupied Bandwidth and Adjacent Channel Power must be performed. Most operators want to set their transmitters to the maximum licensed power to maximize range from the base station. The Channel Power measurement is ideal to help set this up. 5G transmitters use time division duplex (TDD) frames, where resource blocks are allocated in a fixed pattern to transmit and receive data. To get fast and reliable measurements of Channel Power, OBW, and ACLR it is necessary to set a time gate in the 5G frame that processes spectrum data only on signal within the gate. The gate is set to be in a specified portion of the frame such as the SSB. By triggering using the GPS gate source, the same portion of a 5G frame is analyzed over many trigger events.



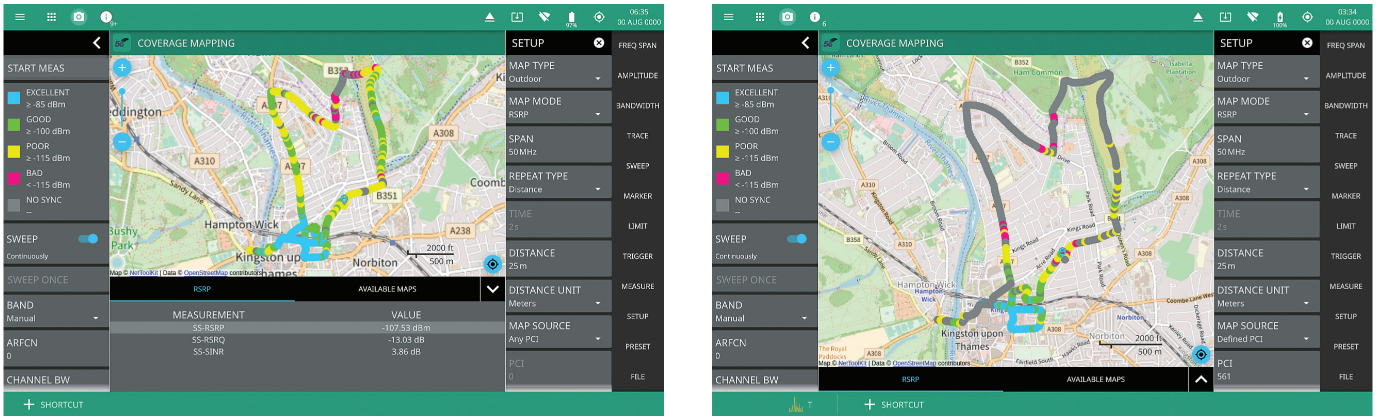

*Field Master MS2080A Channel Power Measurement on 100 MHz 5G Bandwidth Carrier (Left) with Time Domain Gated Sweep Applied (Gate Set Up Shown Right)*

Once the transmitter measurements and 5G demodulation measurements have been completed, a coverage mapping drive confirms that the cell site provides the geographic coverage predicted during network modeling. A coverage mapping measurement drops breadcrumbs on a digital map where the color of the breadcrumb represents the RSRP (or RSRQ/SINR/Channel Power) of the base station under test. This provides a useful indication of the area over which a receiving device (e.g., smartphone) can expect coverage from a given base station. Industry best practice has defined common definitions for signal quality for RSRP and RSRQ based on each frequency band.

| 5G FR1 < 3 GHz | | | |
|---|---|---|---|
| | Definition | RSRP | RSRQ |
| Excellent | Maximum data throughput | > -80 dBm | > -10 dB |
| Good | Good data throughput | -80 dBm to -95 dBm | -10 dB to -12 dB |
| Poor | Maintain data connection with restricted throughput | -95 dBm to -115 dBm | -12 dB to -16 dB |
| Bad | Connection dropped | < -115 dBm | < -16 dB |

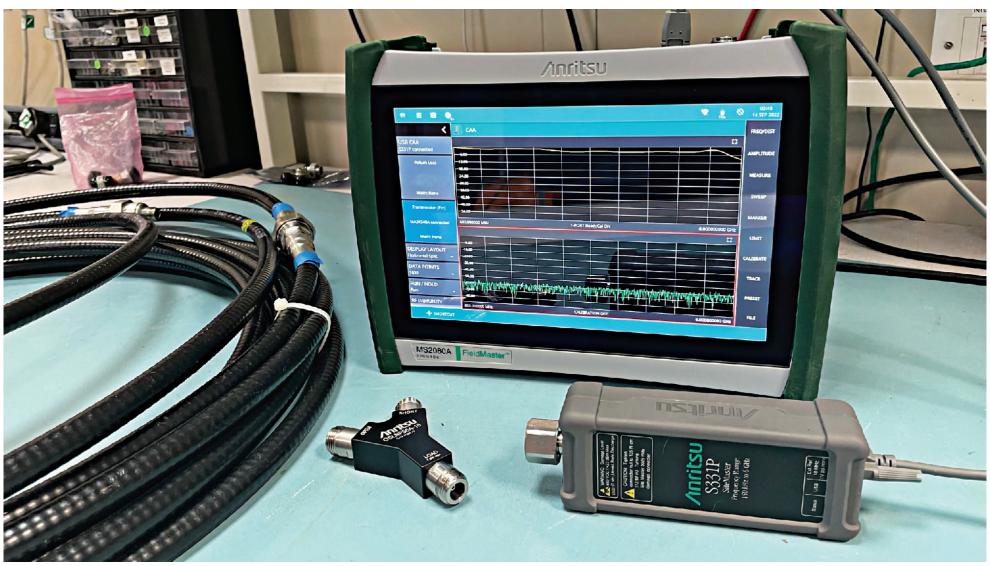
| 5G FR1 3 GHz to 6 GHz | | | |
|---|---|---|---|
| | Definition | RSRP | RSRQ |
| Excellent | Maximum data throughput | > -85 dBm | > -10 dB |
| Good | Good data throughput | -85 dBm to -100 dBm | -10 dB to -12 dB |
| Poor | Maintain data connection with restricted throughput | -100 dBm to -115 dBm | -12 dB to -16 dB |
| Bad | Connection dropped | < -115 dBm | < -16 dB |

When completing a coverage mapping drive, Field Master MS2080A is operated in OTA mode so that it captures data from all base stations in the area. Once the data has been saved at the completion of the drive, a PCI filter enables the coverage from individual base stations to be reviewed. Without applying a PCI filter, the overall network coverage from all base stations presented.




*5G Coverage Highlighting Results From all PCIs (Left) and Filtered to Show Only Coverage from 5G Base Station with PCI 561 (Right)*

Field Master MS2080A offers regulators and network operators a comprehensive and portable instrument that performs the essential measurements required for 5G base station installation and maintenance. In addition to the 5G measurements, options are available to add RF cable and antenna line sweep tests and a real-time spectrum analyzer to aide interference hunting. All packaged in a rugged, portable, and battery powered instrument.




*Field Master MS2080A with Site Master S331P*

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• **United States**
**Anritsu Americas Sales Company**
450 Century Parkway, Suite 190, Allen, TX 75013 U.S.A.
Phone: +1-800-Anritsu (1-800-267-4878)

• **Canada**
**Anritsu Electronics Ltd.**
700 Silver Seven Road, Suite 120, Kanata,
Ontario K2V 1C3, Canada
Phone: +1-613-591-2003
Fax: +1-613-591-1006

• **Brazil**
**Anritsu Eletronica Ltda.**
Praça Amadeu Amaral, 27 - 1 Andar
01327-010 - Bela Vista - Sao Paulo - SP, Brazil
Phone: +55-11-3283-2511
Fax: +55-11-3288-6940

• **Mexico**
**Anritsu Company, S.A. de C.V.**
Blvd Miguel de Cervantes Saavedra #169 Piso 1, Col. Granada
Mexico, Ciudad de Mexico, 11520, MEXICO
Phone: +52-55-4169-7104

• **United Kingdom**
**Anritsu EMEA Ltd.**
200 Capability Green, Luton, Bedfordshire, LU1 3LU, U.K.
Phone: +44-1582-433200
Fax: +44-1582-731303

• **France**
**Anritsu S.A.**
12 avenue du Québec, Immeuble Goyave,
91140 VILLEBON SUR YVETTE, France
Phone: +33-1-60-92-15-50

• **Germany**
**Anritsu GmbH**
Nemetschek Haus, Konrad-Zuse-Platz 1,
81829 München, Germany
Phone: +49-89-442308-0
Fax: +49-89-442308-55

• **Italy**
**Anritsu S.r.l.**
Spaces Eur Arte, Viale dell'Arte 25, 00144 Roma, Italy
Phone: +39-6-509-9711

• **Sweden**
**Anritsu AB**
Kistagången 20 B, 2 tr, 164 40 Kista, Sweden
Phone: +46-8-534-707-00

• **Finland**
**Anritsu AB**
Technopolis Aviapolis, Teknobulevardi 3-5 (D208.5.),
FI-01530 Vantaa, Finland
Phone: +358-20-741-8100

• **Denmark**
**Anritsu A/S**
c/o Regus Winghouse, Ørestads Boulevard 73, 4th floor,
2300 Copenhagen S, Denmark
Phone: +45-7211-2200

• **Russia**
**Anritsu EMEA Ltd.**
**Representation Office in Russia**
Tverskaya str. 16/2, bld. 1, 7th floor., Moscow, 125009, Russia
Phone: +7-495-363-1694
Fax: +7-495-935-8962

• **Spain**
**Anritsu EMEA Ltd.**
**Representation Office in Spain**
Paseo de la Castellana, 141. Planta 5, Edificio Cuzco IV
28046, Madrid, Spain
Phone: +34-91-572-6761

• **Austria**
**Anritsu EMEA GmbH**
Am Belvedere 10, A-1100 Vienna, Austria
Phone: +43-(0)1-717-28-710

• **United Arab Emirates**
**Anritsu EMEA Ltd.**
**Anritsu A/S**
Office No. 164, Building 17, Dubai Internet City
P. O. Box – 501901, Dubai, United Arab Emirates
Phone: +971-4-3758479

• **India**
**Anritsu India Private Limited**
6th Floor, Indiqube ETA, No.38/4, Adjacent to EMC2,
Doddanekundi, Outer Ring Road, Bengaluru – 560048, India
Phone: +91-80-6728-1300
Fax: +91-80-6728-1301

• **Singapore**
**Anritsu Pte. Ltd.**
11 Chang Charn Road, #04-01, Shriro House, Singapore 159640
Phone: +65-6282-2400
Fax: +65-6282-2533

• **Vietnam**
**Anritsu Company Limited**
16th Floor, Peakview Tower, 36 Hoang Cau Street, O Cho Dua Ward,
Dong Da District, Hanoi, Vietnam
Phone: +84-24-3201-2730

• **P.R. China (Shanghai)**
**Anritsu (China) Co., Ltd.**
Room 2701-2705, Tower A, New Caohejing International
Business Center No. 391 Gui Ping Road Shanghai, 200233, P.R. China
Phone: +86-21-6237-0898
Fax: +86-21-6237-0899

• **P.R. China (Hong Kong)**
**Anritsu Company Ltd.**
Unit 1006-7, 10/F., Greenfield Tower, Concordia Plaza,
No. 1 Science Museum Road, Tsim Sha Tsui East,
Kowloon, Hong Kong, P.R. China
Phone: +852-2301-4980
Fax: +852-2301-3545

• **Japan**
**Anritsu Corporation**
8-5, Tamura-cho, Atsugi-shi, Kanagawa, 243-0016 Japan
Phone: +81-46-296-6509
Fax: +81-46-225-8352

• **Korea**
**Anritsu Corporation, Ltd.**
5FL, 235 Pangyoyeok-ro, Bundang-gu, Seongnam-si,
Gyeonggi-do, 13494 Korea
Phone: +82-31-696-7750
Fax: +82-31-696-7751

• **Australia**
**Anritsu Pty. Ltd.**
Unit 20, 21-35 Ricketts Road, Mount Waverley, Victoria 3149, Australia
Phone: +61-3-9558-8177
Fax: +61-3-9558-8255

• **Taiwan**
**Anritsu Company Inc.**
7F, No. 316, Sec. 1, NeiHu Rd., Taipei 114, Taiwan
Phone: +886-2-8751-1816
Fax: +886-2-8751-1817


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