

Over-the-Air Testing of 5G Millimeter-Wave Radios

Introduction

After years of hype, the world is quickly being introduced to 5G. Country by country and provider by provider, this can mean different things. Much of the world is focusing initial 5G rollouts on the 3GPP defined FR1 bands (those carriers with frequencies below 6 GHz). South Korean operators, for example, have launched the world's first full-scale 5G network in the 3.5 GHz bands, with over 100,000 base stations already installed. Several countries across Europe have brought commercial services to market and Japan and China will soon do the same. Other countries and carriers, like in the US, are focusing much more attention on FR2 – or millimeter-wave (mmWave) – frequencies. This could be for several reasons, including the availability of spectrum or the wider bandwidths that are open in the mmWave bands, typically around 24, 28, and 39 GHz. Around the world, the widest allotment of spectrum for FR1 5G is 100 MHz or less. While this amount of bandwidth will provide much higher performance over legacy wireless standards, it isn't the best 5G can do. The 3GPP standard defines single carriers up to 400 or 800 MHz channels made up of side-by-side aggregated carriers. That kind of open frontier cannot be found in FR1, but FR2 is much more wide open.

This application note will discuss some of the differences in mmWave 5G NR signals versus sub-6 GHz and the challenges that introduces. It will then go into some methods for testing mmWave frequencies over-the-air (OTA) to clear spectrum, hunt interference, and verify installation/operation using Anritsu's Field Master Pro™ MS2090A handheld spectrum analyzer.

mmWave versus Sub-6 GHz

As mentioned earlier, there are practical differences between FR1 and FR2 signals. There are also technological differences that will impact performance and testing. Per the 3GPP standard, mmWave 5G NR signals have subcarrier spacing of either 120 or 240 kHz, compared to only 30 or 60 kHz for FR1. This results in a wider sync signal block (SSB) – 28.8 and 57.6 MHz, respectively. The SSB contains the SSS, PSS, and PBCH information, which are required for demodulation and signal identification. Therefore, any instrument or device must have the capability of capturing wide bandwidths of data (at least as wide as the SSB) in order to make proper ID of and communication with the radio.

FR2 signals also have more SSB beams. All 5G NR base stations transmit SSB beams through the antenna's transmission sector, but mmWave radios use between 12 and 64 beams, whereas FR1 radios are limited to four or eight beams. With 64 beams, the radio can transmit narrower beams with more power, which improves the efficiency of the radio and helps avoid interference. However, more beams requires decoding more bits from the PBCH in order to read out all 64 beam indexes in their correct position. It also requires a greater number of antenna elements in the antenna array used for beam forming. This makes it impossible to do connected testing and verification of the radios, forcing users to do all testing OTA.

Finally, mmWave signals have shorter wavelengths (as hinted in the name), which will cause greater propagation loss through both air and most physical objects – including windows, which are often coated with UV protective films which strongly attenuate mmWave RF. This means 5G mmWave service will require greater radio density and strategic placement/alignment. It will also make signals more vulnerable to interference, and requires test equipment with lower noise floors and faster sweep speeds in the mmWave bands.

Testing 5G NR mmWave

Spectrum Clearing and Interference Finding

Wireless providers pay billions of dollars for the rights to transmit signals within certain frequency blocks. It's no wonder they will also go to great lengths to protect those blocks from unknown and/or unwanted radio traffic that would interfere with clean transmission of the 5G signals. This is especially true in mmWave where the signals are especially vulnerable to interference, given the high amounts of path loss in transmission.

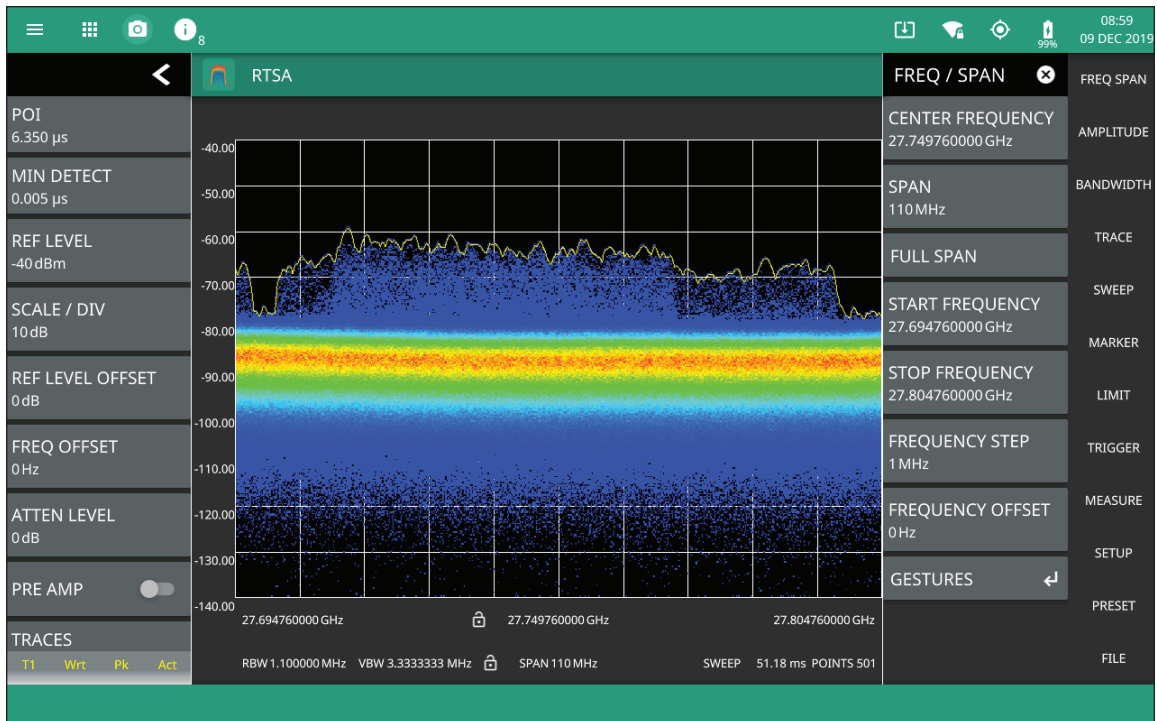
The Field Master Pro MS2090A handheld real-time spectrum analyzer provides several valuable solutions for spectrum clearing at mmWave. To begin, users can use the Field Master Pro MS2090A in conjunction with Anritsu's Mobile InterferenceHunter™ to map out their coverage area and identify any hot spots with potential RF energy. They can then pinpoint the location of the potential interference and work to clear it out.



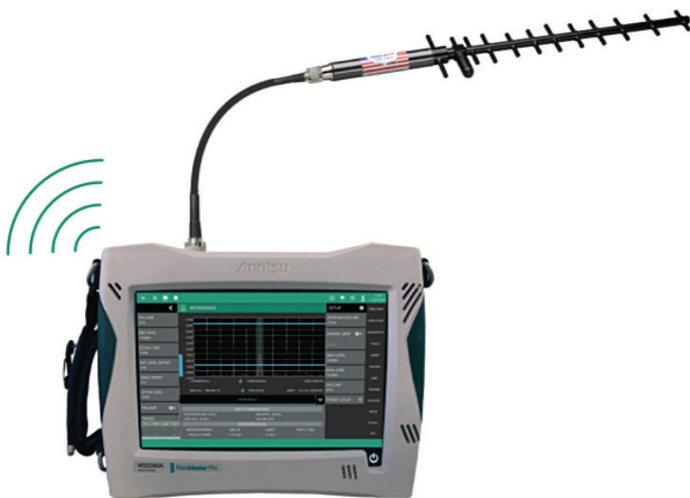
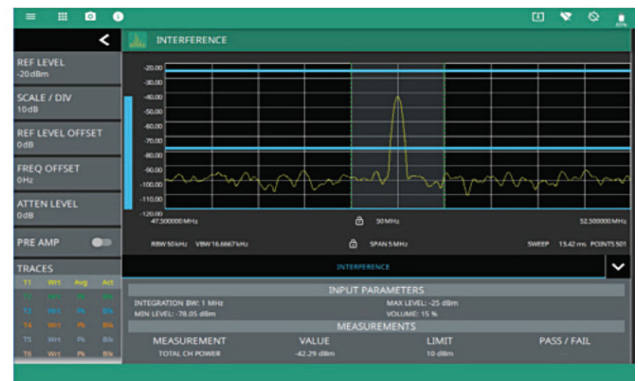
The Field Master Pro MS2090A also offers 110 MHz of real-time spectrum analyzer (RTSA) bandwidth and power density display to watch out for difficult-to-find, intermittent interference. With an omni-directional antenna, the instrument can be setup in an infinite persistence and left to run for minutes or hours to ensure no signals are present. If a signal does pop up, the instrument can then be tuned to the frequency of interest and a directional antenna can be used to find the source of the signal.



The Field Master Pro MS2090A RTSA Has an Infinite Persistence Setting to Capture any Signal Movement over a Long Period of Time During Spectrum Monitoring



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

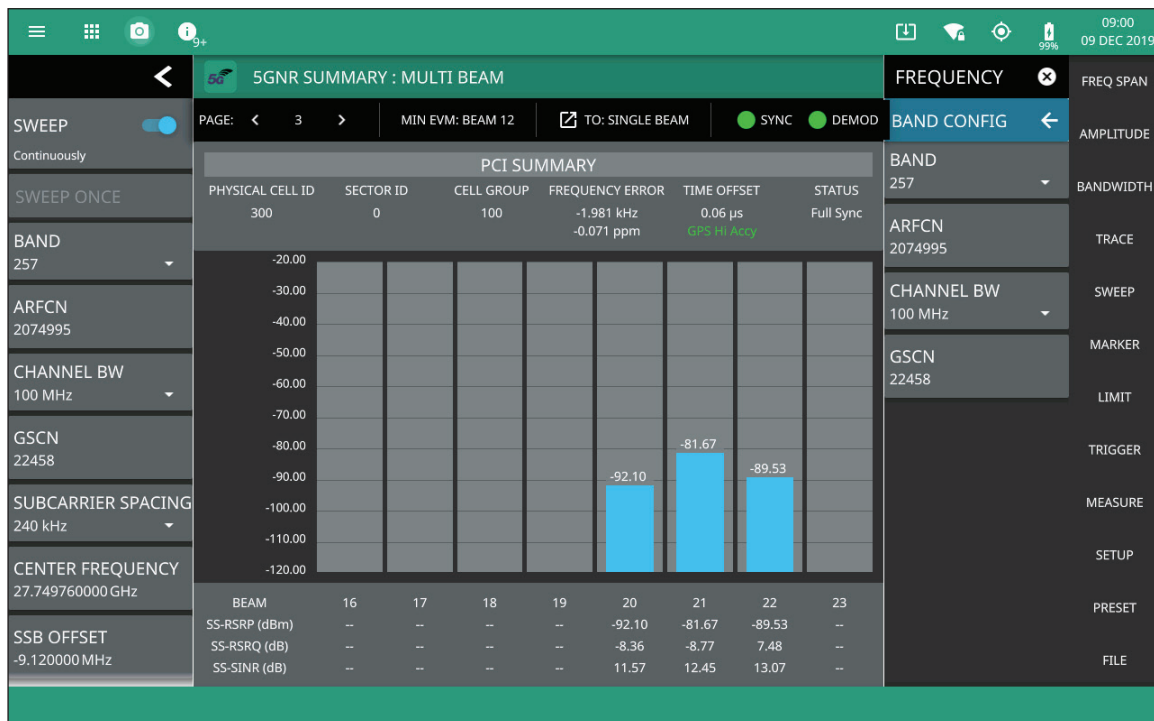


Interference Finder Option 24 Provides Fast Audio Tone Response to Changing Interference Levels

Installation Verification

Once spectrum is clear and radios are going up, it will be key to ensure the radios are configured correctly and performing per standard. The Field Master Pro MS2090A offers a full 5G NR demodulation suite, which decodes the SSB beams to provide the following information:

- Cell ID, Sector ID, and Cell Group
- Frequency error
- Time offset
- Individual beam RSRP, RSRQ, and SINR
- EVM of the individual SSB parts
- Multi cell measurements
- Channel power/occupied bandwidth



Field Master Pro MS2090A 5G NR Demodulation Summary Screen

Single Cell Testing

ID information is important for verifying the configuration of the radios. Network operators rely on proper radio identification to pinpoint issues with service, interference, or gaps in coverage. Cells are usually hung in groups of three, each covering one of three sectors. The cell ID is then equal to $3 \times \text{CELL GROUP} + \text{SECTOR ID}$.

PHYSICAL CELL ID	SECTOR ID	CELL GROUP
300	0	100

Frequency error is key to performance, where less error promotes greater signal quality and faster throughputs. According to the 3GPP standard for 5G NR OTA testing (TS 38.104, section 6.5.1.2), the base station frequency error should comply as follows:

BS Class	Accuracy
Wide Area BS	±0.05 ppm
Medium Range BS	±0.1 ppm
Local Area BS	±0.1 ppm

FREQUENCY ERROR

-1.981 kHz

-0.071 ppm

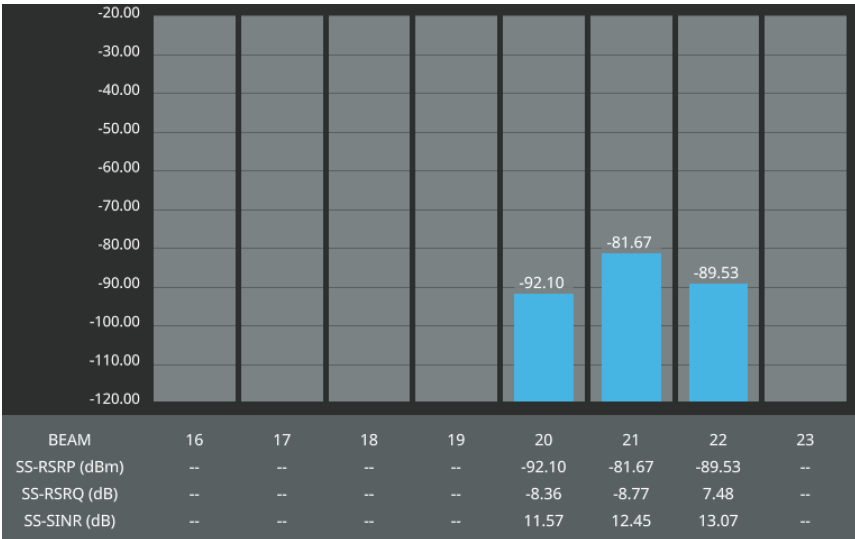
Time offset is key to full network performance. All 5G NR signals should be tightly synchronized to GPS. Time offset measures the difference between the GPS clock and the start of the frame. This avoids interference between cells. Per the 3GPP standard, the time offset should not exceed 2 μs at a distance less than 1 km.

TIME OFFSET

0.06 μs

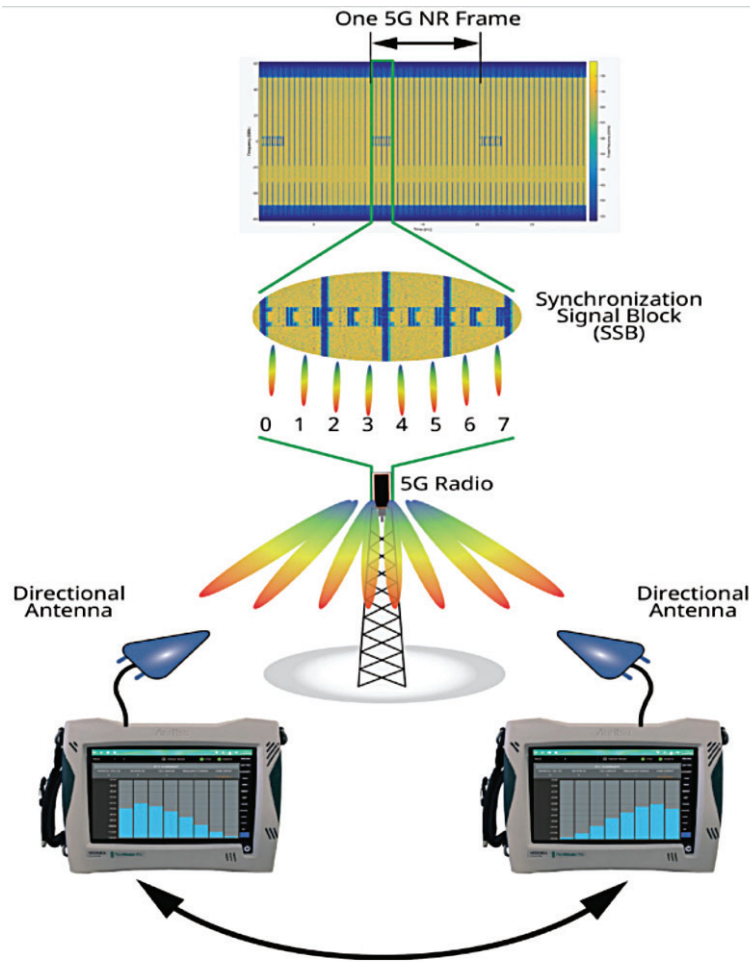
GPS Hi Accy

RSRP, RSRQ, SINR, and EVM are key indicators of radio performance and signal quality. The average EVM of the signals should typically be under 15% with a high quality beam (one with high RSRP and SINR).

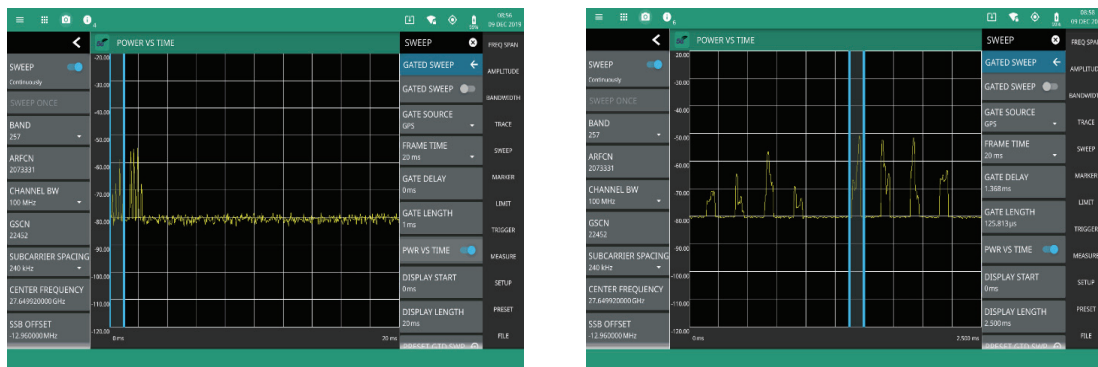


Beam information can be viewed either per individual beam or from the multi-beam view. Multi-beam is especially useful when checking radio alignment. Each radio installation should cover a very specific sector of geography. With the multi-beam view, a user can walk from one side of the radio sector to the other and watch as the different beams rise and fall in power to coincide with the instrument’s position relative to the radio. If the radio has been aligned correctly, the correct beams will show the highest power at the edge of the sector. Channel power and occupied bandwidth measurements can show compliance to power and frequency regulations, as well as relative performance in different environments, like indoors versus outdoors.

****See side note on gating****



Field Master Pro MS2090A Displays RSRP vs Beam Index Based on OTA Analysis of the 5G NR SSB

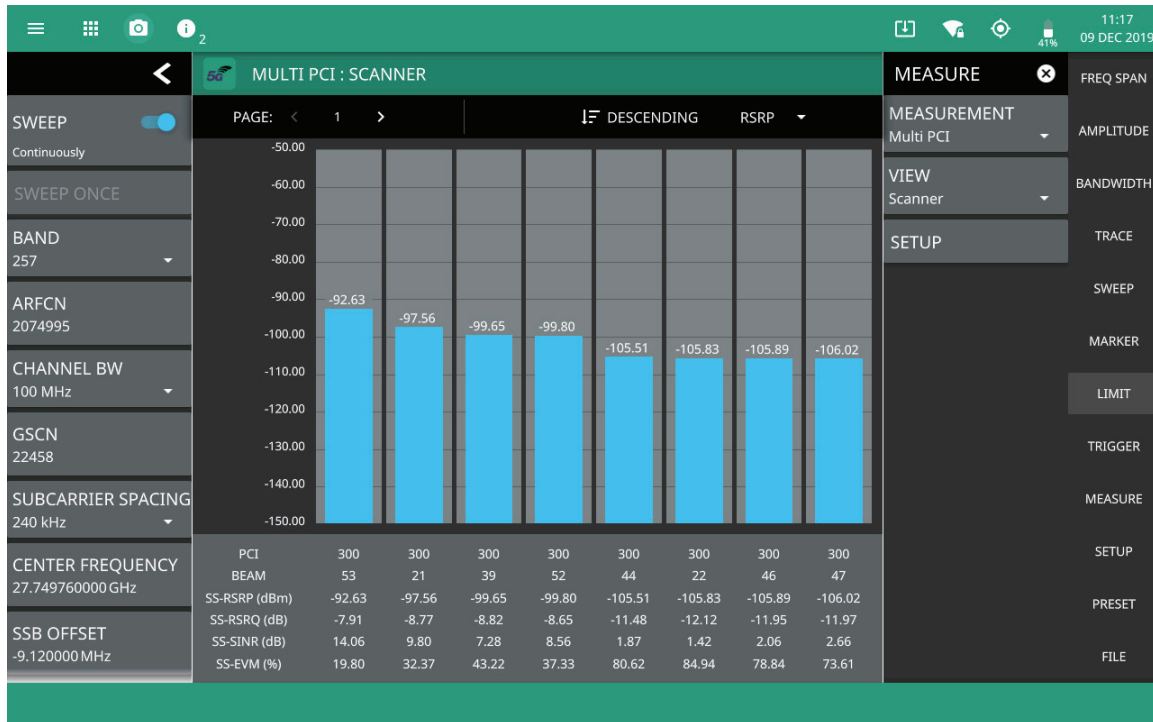


Time Gating

5G NR transmissions are time division duplex (TDD) signals, which means the radio will be constantly switching between SSB, downlink, and uplink over time. This happens rapidly, as the 5G NR frame is only 10 ms. When making RF measurements on the base station, the analyzer is typically only measuring the SSB and downlink power, so trace will rise and fall rapidly as the radio switches. This makes it very difficult to make accurate power or bandwidth measurements on the signal because the power fluctuates so much. In order to make stable RF measurements of the signal, the Field Master Pro MS2090A supports time gating. This enables users to focus the analyzer results on a specific section of time within the frame. In this example, RF is only present during the transmission of the SSBs. Zooming in and setting the gate on the SSB transmission allows users to read the SSB channel power and bandwidth.

Multi Cell

The Field Master Pro MS2090A also offers a measurement of multiple radios in the same capture (called Multi Cell in the instrument). By utilizing advanced noise cancellation methods, it is able to read out multiple cell IDs for a single geographic point and show the RSRP of every beam from strongest to weakest. This is powerful for mapping coverage in these dense radio environments. Network planners can utilize the Multi Cell measurement to identify radio handoff points and possible gaps in coverage, even mapping out the coverage, cell by cell.



Conclusion

Anritsu's Field Master Pro MS2090A is specially designed to handle the challenges of mmWave installation and maintenance. The Field Master Pro MS2090A gives users the most accurate, robust measurements possible and is the first solution to provide:

- Full, uninterrupted frequency coverage from 9 kHz up to 54 GHz allows users to test any 5G NR signal — from FR1 to FR2 and anything in between
- Industry-best specification performance with low noise floor (DANL) to find low power signals or interference
- Excellent phase noise for signal quality measurements



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List Revision Date: 20240416



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11410-01162, Rev. B Printed in United States 2024-04
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