# Six Essential Field Tests - 5G

## USING FIELDFOX HANDHELD ANALYZERS




KEYSIGHT

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# Introduction

The fifth generation of cellular technology pushes the boundaries of the networks we know today. 5G will fuel technologies such as autonomous cars, Internet of Things (IoT) devices, virtual reality, and livestreaming videos. The unprecedented capabilities and improvements that 5G promises will require accurate field test methods for deployment.

This eBook introduces six essential field tests for 5G installation, verification, optimization, and troubleshooting using the FieldFox handheld analyzer. Ensure a smooth 5G network transformation and achieve expected network performance with these test options in your field kit:

1. Path loss characterization
2. Base station coverage testing
3. Component carrier power measurements
4. Over-the-air control channel coverage testing
5. Network quality and beam performance verification
6. EMF exposure evaluation

# Contents

## Six Essential 5G Field Tests Using FieldFox Handheld Analyzers

## TEST 1

# Path Loss Characterization

TEST 1
# Path Loss Characterization

Many factors affect millimeter-wave (mmWave) coverage — rain, foliage, free space, buildings, mountains, distance, and more. All of these conditions cause an electromagnetic wave to lose power density as it propagates through space. The loss in power density is known as path loss.

Understanding the path loss of a telecommunications system is critical for determining the link budget of that system. The link budget is the accounting of all the gains and losses experienced by a signal sent from transmitter to receiver. Since mobile user location is unpredictable, service providers have to consider every potential obstruction to their signals. So, determining an accurate link budget is essential for planning and rolling out 5G networks.

Since path loss plays a significant role in establishing a link budget, having test equipment capable of making path loss measurements in the field is imperative. These measurements help ensure the quality of 5G coverage in varying terrain, weather, and air quality.

To find out more about mmWave link propagation and link budget, read the application note *5G Over-the-Air Performance Measurement and Evaluation Using FieldFox Handheld Analyzers.*

## LEARN MORE

Application Note: *5G Over-the-Air Performance Measurement and Evaluation Using FieldFox Handheld Analyzers.*

# Path Loss Characterization with FieldFox

To characterize path loss, you need two FieldFox devices. One acts as the transmitter and the other as the receiver. Each FieldFox has a built-in continuous waveform generator capable of generating frequencies between 300 kHz and 50 GHz. You may add an amplifier, which the FieldFox can power on its own.

Path loss measurements for mmWave are made over the air via a radio link. The transmitting FieldFox uses a gain horn antenna, and the receiving FieldFox uses either an omnidirectional antenna or a gain horn antenna. The FieldFox on the receiving side makes the signal strength measurement in Spectrum Analyzer or Real-Time Spectrum Analyzer mode. You can record the data in a stationary manner or during a drive test. FieldFox saves the data with GPS and timestamp information so you can load the data into planning software.

## LEARN MORE

Watch this video to see how FieldFox works with Keysight's Nemo Outdoor to verify 5G propagation models.

**TEST 2**

# Base Station Coverage Testing

**TEST 2**

# Base Station Coverage Testing

For 4G LTE base station coverage testing, RF engineers use scanning receivers with omnidirectional antennas to detect coverage gaps. These antennas, which receive energy from all directions, match mobile phone antenna characteristics. When connected to a scanning receiver, the solution measures signal strength and control channel power from the LTE base station, also called Evolved Node B or eNB. It logs one data point per geolocation and makes several measurements in the same location for better statistical values.

Since 5G uses massive multiple-input, multiple-output (MIMO) and beamforming technology to reach users, shown in Figure 1, omnidirectional antennas are not feasible. Instead, the antennas of receiving mobile phones and transmitting base stations are phased array antennas. Coverage testing of 5G base stations — also called Next Generation Node B or gNB — requires a spectrum analyzer or scanning receiver equipped with a phased array antenna. Additionally, because of the nature of beamforming, just logging geolocation points is not enough. RF engineers must collect signal power data from the gNB across azimuth and elevation.

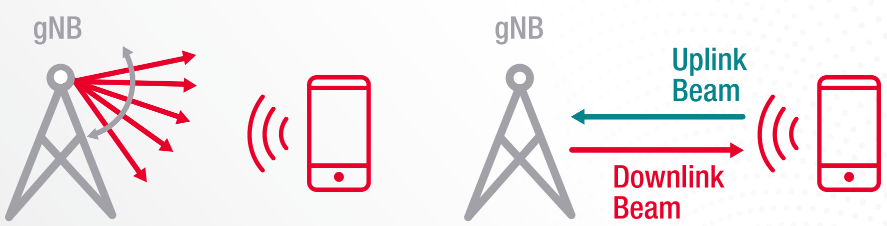


Figure 1. Depiction of 5G NR beamforming and beam sweeping

# Base Station Coverage Testing with Fieldfox

To perform gNB coverage tests, FieldFox integrates with an 8x8 phased array antenna as shown in Figure 2. The antenna serves as an RF probe, while FieldFox controls the measuring beam. FieldFox sweeps the beam from 0 to 120 degrees in azimuth and 0 to 90 degrees in elevation. It then captures and logs three data points: azimuth, elevation, and amplitude. The built-in GPS receiver also records geolocation information.

FieldFox can generate a heat map display to show two-dimensional coverage of azimuth versus elevation. It can also display the polar antenna pattern to understand the beam characteristics of the gNB phased array antennas or perform a boresight scan to verify antenna performance.

Find out more about the FieldFox and phased array antenna solution in this technical overview.

Figure 2. FieldFox and phased array antenna set up

**TEST 3**

# Component Carrier Power Measurements

**TEST 3**

# Component Carrier Power Measurements

If a base station is not transmitting at optimal power, it affects coverage, neighboring cells, or both. Because of these effects, telecommunications companies — especially those deploying and maintaining 5G — must verify component carrier power levels in the field. When deploying or maintaining service, this sort of verification helps providers pinpoint faulty base stations (otherwise known as towers). Pinpointing the culprit in an area that may have several towers enables coverage optimization and prevents tower power from leaking into neighboring frequency bands.

# Component Carrier Power Measurements with FieldFox

FieldFox can perform over-the-air (OTA) component carrier power measurements in Channel Scanner mode, shown in Figure 3. It offers a simple way to measure power levels from different LTE and 5G base stations in a single measurement. FieldFox can monitor up to 20 channels, with customizable frequency and integration bandwidth settings for each channel. Using the FieldFox built-in GPS receiver, you can measure channel power versus location or channel power versus time and log that data with geotagging.

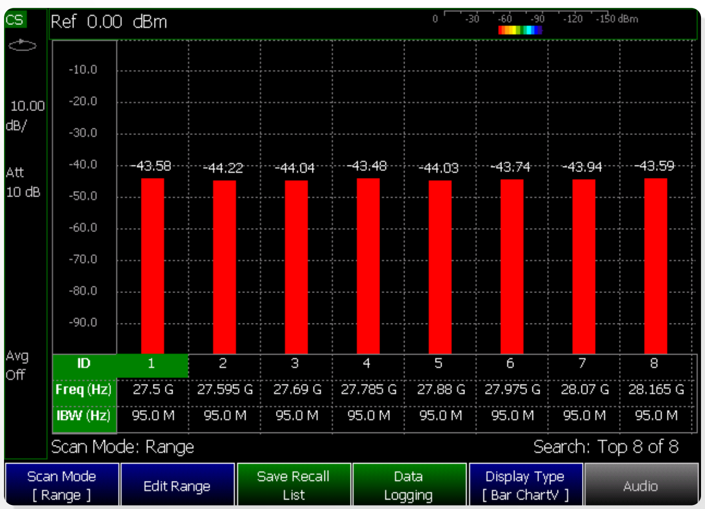


Figure 3. Component carrier power measurements captured using a FieldFox

TEST 4

# Over-the-Air Control Channel Interference Testing

**TEST 4**

# Over-the-Air Control Channel Interference Testing

The rollout of 5G and an ever-increasing number of wireless technologies introduces many opportunities for interference. 5G base stations, for instance, can create interfering signals for nearby satellite ground stations, depicted in Figure 4. Some of those satellite ground stations may be responsible for emergency radio communications. Interfering with such critical communications could cause a disaster. That is one reason why identifying interfering signals in the field when developing and deploying 5G networks is so crucial.

Additionally, adjacent cells can cause interference between each other. If the data channels are interfering, the speeds at which these signals travel are too fast for the interference to impact network performance. If interference occurs in the control channel on the other hand, it can bring down the whole cell site.

Proper control channel transmissions are essential for field deployment. Having a solution in your field kit that is capable of capturing interference signals and visualizing control channels will facilitate your 5G transformation

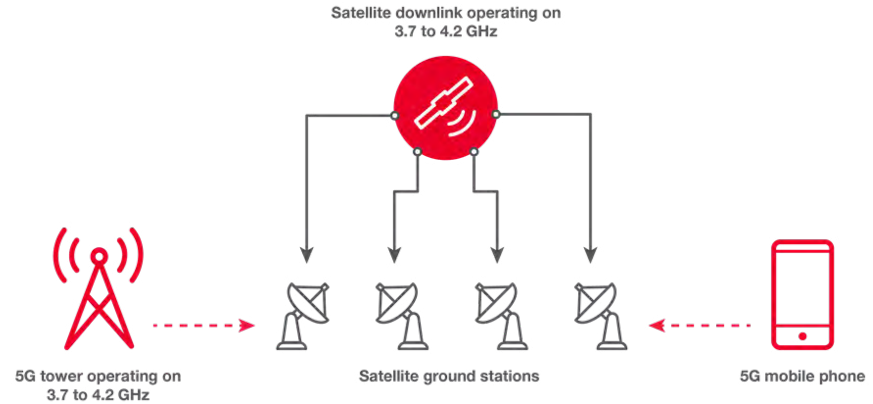


Figure 4. 5G radio tower and mobile phone interfering with satellite ground station communications

> Identifying interfering signals in the field when developing and deploying 5G networks is **crucial.**

PATH LOSS | BASE STATION COVERAGE | COMPONENT CARRIER | CONTROL CHANNEL | NETWORK QUALITY | EMF EXPOSURE

# Over-the-Air Control Channel Interference Testing with FieldFox

When paired with the phased array antenna mentioned before, FieldFox in RTSA (Real-Time Spectrum Analysis) mode facilitates cell search, and displays beam sweep signals, seen in Figure 5. This view includes the primary, secondary, and extended synchronization signals in the control channel. From this display, you can see any interfering or transient signals and measure beam performance.

> FieldFox is compatible with Keysight's **Spectrum Monitoring Software,** which offers spectrum monitoring, logging, and management, plus interference detection and location.

RTSA mode also allows you to measure and visualize the synchronization signal block (SSB) of a transmission, portrayed in Figure 6. Should any interference occur, FieldFox will capture that interfering signal and display it on the screen.

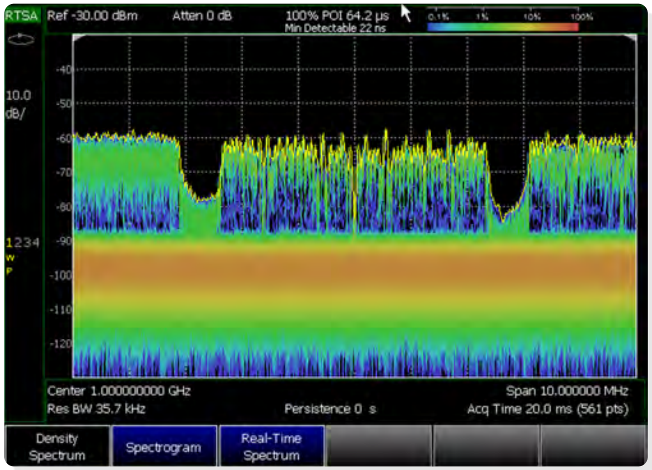


Figure 5. Beam sweep signals captured using FieldFox in RTSA mode

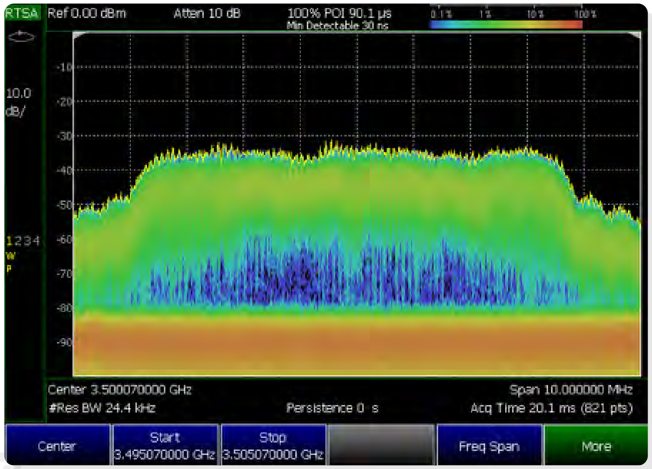


Figure 6. SSB measurements made using FieldFox in RTSA mode

5G

**TEST 5**

# Network Quality and Beam Performance Verification

PATH LOSS | BASE STATION COVERAGE | COMPONENT CARRIER | CONTROL CHANNEL | 5G NETWORK QUALITY | EMF EXPOSURE

TEST 5

# Network Quality and Beam Performance Verification

When a 5G NR base station sweeps signal beams over time, each beam is known as an SSB, and has an assigned index number. Each SSB represents a specific beam radiated in a certain direction.

Cell phones detect various SSBs from different towers and measure them to determine which is the strongest. Once the cell phone pinpoints the SSB with the most signal strength, it connects using that particular beam. A beam that is strongest for one user may not be the strongest for another user near the same tower.

When transitioning to 5G, operators have to verify the quality of their network and beam performance so users can connect without issue. To do this, you need a solution in your field kit that is capable of reading and displaying important metrics from several base stations in the vicinity. These metrics include channel power, signal quality, SSB index, and frequency error from various base stations.

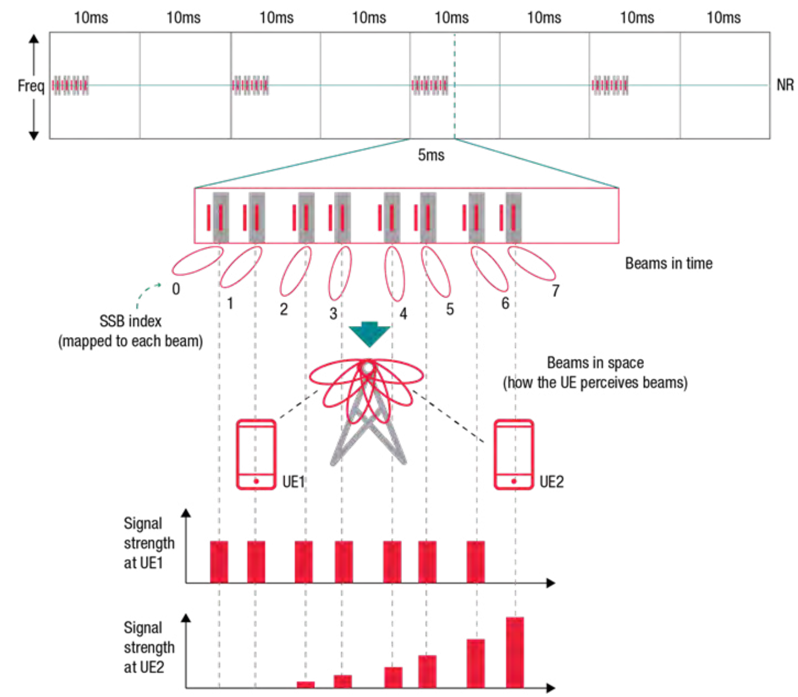


Figure 7. 5G NR initial access procedure for UE (user equipment) connection

# Network Quality and Beam Performance Verification with FieldFox

FieldFox has built-in measurements for LTE frequency division duplex (FDD) and 5G NR that provide key performance indicator (KPI) metrics. These metrics include reference signal received power (RSRP), reference signal received quality (RSRQ), received signal strength indicator (RSSI), and more. In addition to the displayed metrics, you can also see how many cells are available for LTE and 5G. This capability is important for initial 5G deployments of non-standalone (NSA) mode, where operators rely on cell phone handoffs between LTE and 5G networks.

FieldFox's 5G NR OTA mode demodulates 5G NR signals to provide frequency, physical cell ID, SSB index, frequency error, and other KPIs for up to eight base stations. It also delivers several channel power measurements, including the primary and secondary synchronization signals. From this information, users can identify any frequency drifting, isolate power issues, and investigate performance problems. Using both 5G NR and LTE FDD modes allows for verification of inter-RAT handovers. These measurements are imperative for optimizing network coverage for 5G. They help you determine 5G coverage versus LTE coverage in a certain area. Having that information can help you engineer the LTE network to provide backup when there is not enough 5G coverage. To find out more about 5G NSA mode deployment and how interference affects it, read the application note *Overcoming RF & MW Interference Challenges in the Field.*

## LEARN MORE

Application Note: *Overcoming RF & MW Interference Challenges in the Field.*

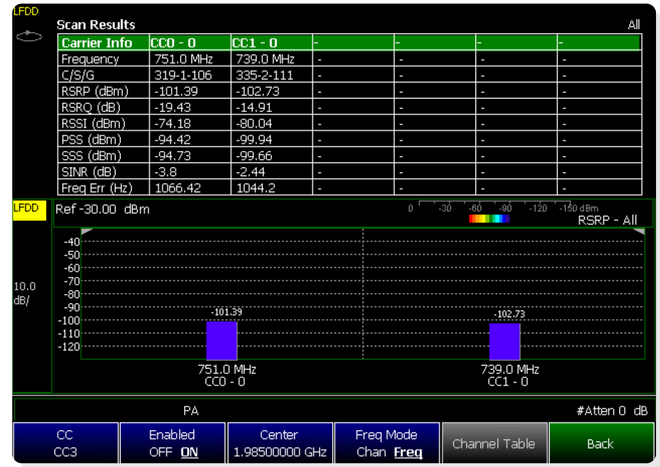


Figure 8. LTE FDD KPI metrics measured in FieldFox's Channel Scanner mode

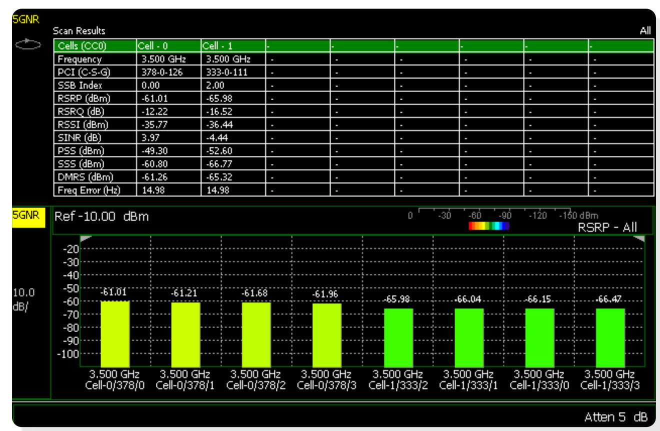


Figure 9. 5G NR OTA mode scans for 5G NR base stations and provides KPI metrics

**TEST 6**

# EMF Exposure Evaluation

**TEST 6**

# EMF Exposure Evaluation

The characteristics of 5G signals require more base station antennas than LTE — especially in densely populated areas. In addition to an increasing number of antennas, 5G mmWave signals have different electromagnetic field (EMF) properties than previous standards. Because of this, operators will have to verify EMF exposure levels in the field for compliance. In order to adhere to set limits and maintain a safe environment for the public and workers, companies implementing 5G must verify their EMF levels during deployment.

> In order to adhere to set limits and maintain a safe environment for the public and workers, companies implementing 5G *must* verify their EMF levels during deployment.

Exposure limits for EMF radiation differ by country. Many countries base their regulations on findings from organizations such as the International Commission on Non-Ionizing Radiation Protection (ICNIRP), the Institute of Electrical and Electronics Engineers (IEEE), and the US Federal Communications Commission (FCC).

# EMF Exposure Evaluation with FieldFox

Various RF and microwave networks — such as mobile phones, base stations, Wi-Fi, smart meters, IoT devices, and satellite and radar systems — create EMF radiation. RF EMF tests in the field are key to evaluating total RF exposure in any given area. These tests aid compliance and verification of exposure levels set by government and regulatory agencies.

Both Spectrum Analyzer and 5G NR OTA modes on FieldFox support EMF measurements. You can measure total field strength across the frequency band of interest and use pass / fail limit testing. FieldFox's EMF measurements support connectivity to a triaxial isotropic antenna. The antenna attaches to the FieldFox in two locations — Port 1 and the USB port. The USB automatically transfers the antenna X, Y, and Z factors to the FieldFox unit through the USB connection while FieldFox controls the antenna.

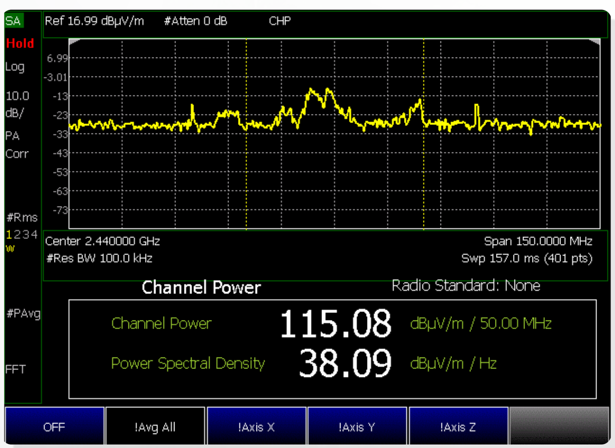


Figure 10. EMF measurements made using FieldFox in Spectrum Analyzer mode

# Summary

A smooth 5G transition requires several essential field tests:

1. Path loss characterization
2. Base station coverage testing
3. Component carrier power measurements
4. Over-the-air control channel coverage testing
5. Network quality and beam performance verification
6. EMF exposure evaluation

Keysight's B-Series FieldFox enables a smooth 5G transition with the capabilities mentioned here plus many more. With a frequency range of up to 54 GHz and bandwidth up to 120 MHz, make 5G field testing a possibility with the FieldFox handheld analyzer.

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