Application Note

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# Solving 5G Coverage Mapping and mmWave Test Challenges with the Anritsu Spectrum Master™ MS2760A Ultraportable Spectrum Analyzer and TRX NEON® MA8100A Signal Mapper

## Overview of 5G Technology and How it Will Present New Test Challenges

The advent of 4G LTE cellular networks was a big leap forward for the world of mobile data by providing users with data transfer bandwidths capable of enabling full internet on-the-go. Today's 4G networks can support bandwidths up to 20 MHz wide; LTE advanced can theoretically go as high as gigabit rates. Some of the new technologies that enable this increase in bandwidth include: 256 QAM modulation; 4x4 MIMO (multi-input-multi-output) with 10 spacial streams using 2 high frequency carriers with 4 layers each and 1 low frequency carrier with 2 layers; and, the use of multi-carrier aggregation or bonding of multiple 20 MHz channels. But as the demand for mobile data and an increasingly connected world develop, the 4G network will struggle to keep up.


5G networks will provide wider channel bandwidths and greater data capacity than current 4G networks. Channel bandwidths greater than 200 MHz and data rates of tens of gigabits per second are planned. As with current 4G systems, as 5G networks evolve over time, they will employ new technologies and techniques to increase data throughput even more. Some new techniques and technologies that are essential for 5G networks include massive MIMO, cooperative MIMO, and adaptive beamforming.

Adding to all of the new challenges of testing a brand new 5G technology, two development tracks are being proposed. The first track is NR-5G (where NR stands for New Radio). This track will have no backwards compatibility. The second track is LTE-5G. This track will use existing 4G infrastructure and incremental improvements to LTE in support of future 5G applications. LTE-5G is the most probable track to be chosen by operators, as they have made significant investments into 4G already and there are still many operators that are just now upgrading to 4G services. 4G will continue to improve with time as well. Gigabit data rates are already available over current 4G networks. So far, 15 carriers in 11 countries are already deploying Gigabit LTE networks. There are currently an additional 47 carriers around the world looking at, testing, or in the process of deploying Gigabit LTE networks. Qualcomm has a 4G modem, the X20, capable of 1.2 gigabit speeds. The real advantages of 5G will come in massive capacity and low latency, beyond the levels of which 4G technologies can achieve. Availability of spectrum is a key requirement to enable deployment of 5G networks, therefore, both higher and lower frequencies are being considered and many operators are actively testing in these bands. Proposed 5G frequency bands range from below 6 GHz up to 100 GHz.

In the lower frequency range, reallocation of existing bands, such as 600 MHz, 700 MHz, 800 MHz, 900 MHz, 1.5 GHz, 2.1 GHz, 2.3 GHz, and 2.6 GHz, is being considered. These bands may be of particular interest for both traditional and new non-traditional applications, and are key to deliver necessary 5G broadband coverage for applications such as the Internet of Things (IoT), industry automation, and business critical use cases. Parts of the 3300 MHz – 4200 MHz and 4400 MHz – 4990 MHz bands are being considered for first trials and introduction of 5G services in a number of countries and regions in the world, including:

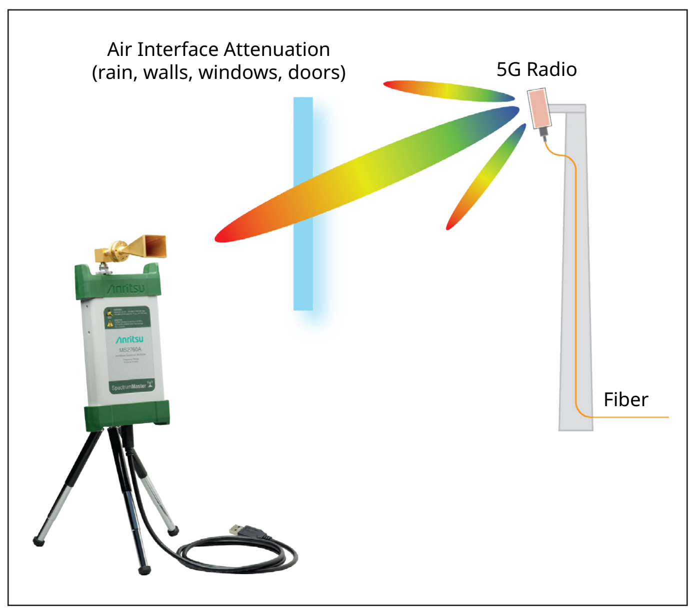
- USA: 3100 – 3550 MHz and 3700 – 4200 MHz
- Europe: 3400 – 3800 MHz
- China: 3300 – 3600 MHz, 4400 – 4500 MHz, and 4800 – 4990 MHz
- Japan: 3600 – 4200 MHz and 4400-4900 MHz
- Korea: 3400 – 3700 MHz

At the higher frequency bands, potential first deployments around the world include:

- USA: 27.5 – 28.35 GHz and 37 – 40 GHz
- EU: 24.25 – 27.5 GHz
- China: 24.25 – 27.5 GHz and 37 – 43.5 GHz
- Japan: 27.5 – 28.28 GHz
- Korea: 26.5 – 29.5 GHz
- Sweden: 26.5 – 27.5 GHz

## Propagation Loss Challenges

Many operators around the world are now testing around 28 GHz and 39 GHz, but these higher frequencies introduce unique challenges. Higher frequency signals have to contend with greater propagation losses both through the air and through cables. At 28 GHz, the free space loss over 5 meters is 75 dB, at 39 GHz it is 78 dB, and at 60 GHz it is 82 dB. The loss is significantly higher compared to the loss of current 4G frequencies at 1.9 GHz of 52 dB or 800 MHz of 44 dB. In addition to free space loss, atmospheric conditions such as rain, fog, and snow will have a larger impact on signal strength at the higher frequencies. It is clear from the free space loss calculations, more base stations will be needed. Macro-cell sizes on 5G networks will be on the order of 200 meters (4G macro-cells can be up to 20 km) and indoor applications will require repeaters or indoor Distributed Antenna Systems.




In general, antenna systems for 5G will need to support higher gain in order to maintain the same or similar range as previous technology generations. New 5G antennas need to be smaller, more numerous, and have higher gain. More advanced antenna steering and scanning techniques will be employed in order to function well at millimeter-wave (mmWave) frequencies. There will be three primary differences in 5G antenna design:

1. The interface between the antenna and the radio frequency front end will be different. These new interfaces will require more sophisticated circuitry to control new features such as hybrid beamforming and cooperative MIMO functionality.
2. Massive MIMO antenna arrays will be used instead of single antennas.
3. Reliance on beam steering is essential to 5G.

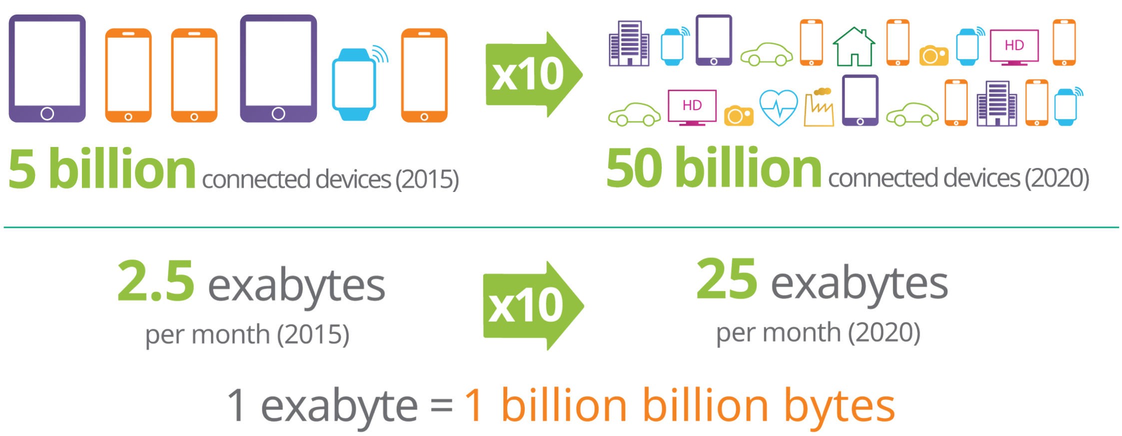
Adding to the complexity, indoor and outdoor materials have different reflection and absorption properties. Typical outdoor materials are more reflective. This means that indoor and outdoor installations will need to take these material properties into consideration.

Some have suggested that outdoor 5G cell sites can transmit to repeaters inside of buildings placed next to windows. However, recent tests of loss through energy efficient “low-e” windows revealed serious propagation problems, as many are coated with metal or metal oxide. Studies have shown that at 28 GHz, attenuation through these coated windows can be as much as 25 to 60 dB. Clear, non-tinted glass has attenuation of about 4 dB. At 28GHz, indoor drywall attenuation is about 7 dB. Adding up the free space loss and losses through different materials, just getting a signal from an outdoor cell site to a user at home or in a cluttered office environment will be a huge challenge.

## The Importance of Low Latency

New use cases will require increased reliability for applications such as critical communications for police, firefighters, ambulance, and other first responders. Vehicle-to-Everything (V2X) communications is another application that requires extremely reliable service. Driverless cars may need 5G network infrastructure before being truly viable commercially. The first generation of driverless cars will be self-contained, but future generations will interact with other cars and smart roads to improve safety and manage traffic. To do this, extremely low latencies and a reliable network connection will be critical. While the cars are all exchanging very small packets of information, any latency or error could be disastrous. When a packet of data shoots directly between two cars or bounces from a car to a small cell on a lamppost to another car, 5G’s sub-millisecond latency will help keep traffic safe and efficient.

## The Growing Need for More Data



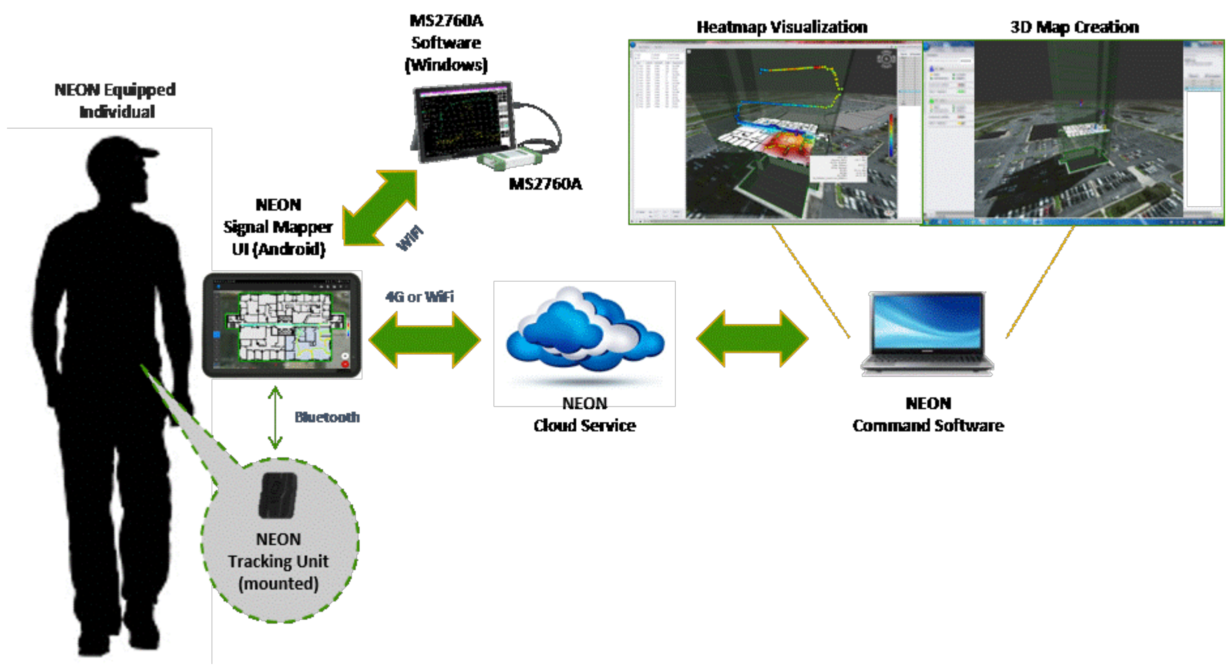

As an example of emerging applications that will require the higher data rates of 5G, Massive Machine to Machine Type Communications (mMTC) — used for IoT — will involve a potentially very large number of small and power-constrained devices, where each device will be transmitting small data packets infrequently. Different mMTC services will exhibit different traffic patterns, which combined with the sheer number of devices, makes the problem of resource allocation very challenging. While the current wireless networks are mainly designed for human type communications, mMTC with its various device types, traffic patterns, and performance requirements will result in very different network structures. Industry analysts predict that 50 billion devices will be connected to mobile networks worldwide by 2020. While mobile phones and other devices communicating among humans (be it voice or data) will account for much of the network usage, machine type devices sending bits of information to other machines, servers, clouds, or humans will account for a much larger proportion in the near future.

## Why is There a Need for In-Building Coverage Measurements

There is a growing demand for commercial wireless providers to increase and improve coverage indoors. Over the past five years, wireless data traffic has increased about 250,000% since 2007 on AT&T's wireless network alone.[1] People are no longer only accessing the Internet at home or in the office, they now expect service anywhere they can bring a mobile device (much of the time inside buildings). To support the increased in-building traffic, network operators, service providers, and even private operators are turning to Distributed Antenna Systems (DAS). A DAS uses a clustered installation of antennas to boost a networks' coverage in areas with weak to no signals. These systems are complex and must be properly designed, installed, and tested.

Commercial wireless service providers, public safety entities, and wireless users expect reliable communications everywhere; whether it be outdoors in the wide open spaces of the countryside or out in the middle of a large city shadowed by tall skyscrapers, inside homes and office buildings, inside of trains in underground tunnels, or at large public spaces like sports arenas, shopping malls, and airports. Providing reliable high bandwidth service to consumers in these different environments is critical to the success of commercial service providers, and is a matter of life and death for public safety entities. Some jurisdictions have enacted ordinances to help ensure that construction of commercial buildings include provisions for radio coverage of public safety signals within the building. Testing of these public safety communications systems must be performed and minimum standards must be met as a condition of occupancy. In addition, initiatives are underway to develop and implement nationwide codes that address public safety for in-building communications.

## Innovative Millimeter-Wave Coverage Mapping Solution




Anritsu's Spectrum Master MS2760A ultraportable spectrum analyzer combined with the Anritsu TRX NEON® MA8100A Signal Mapper is the ideal solution for anyone doing coverage testing of RF and microwave communications systems, including 5G systems operating at the higher (mmWave) frequency bands as well as for testing of indoor DAS systems.

[1] "AT&T Details 5G Evolution." AT&TNEWSROOM, January 4, 2017, http://about.att.com/story/att_details_5g_evolution.html

This solution is capable of supporting both indoor and outdoor coverage mapping needs. While outdoors and in sight of GPS satellites, the system will use GPS data to continuously track the user while making measurements of signal up to 70 GHz. Where GPS is not available, the system employs a tracking unit that supports collection and processing of sensor data that delivers 3D location information. This unique 3D tracking capability provides users with exceptional indoor coverage mapping capabilities that include:

- Eliminating the need to manually perform "check-ins" at each test point by automatically calculating indoor location.
- Providing vastly more data than is possible with manual processes by recording data with every step.
- Removing typical data recording errors caused by "guesstimating" locations in large buildings through automatic indoor location and path estimation.
- Delivering actionable data in areas not easily analyzed, such as stairways and elevators, by recording and referencing measurements in 3D.
- Enabling quick analysis of signal coverage and faster problem resolution by delivering the industry's only geo-referenced 3D visualization.
- Provides color-graded measurement results in 2D and 3D views. Measurement values can be seen by clicking on each point. A .csv file of all measurements is also provided.

Data collection is simple and efficient using Anritsu's integrated Spectrum Master MS2760A and MA8100A solution. Collection time is greatly reduced and data is much more accurate as compared to using non-integrated solutions, where signal information is collected only in 2D at check-in locations or it is interpolated using the limited number of check-ins that have been performed. As a result, data from other systems is often sparse, inaccurate, and time intensive to collect.

## Spectrum Master MS2760A 5G Coverage Mapping System Configuration

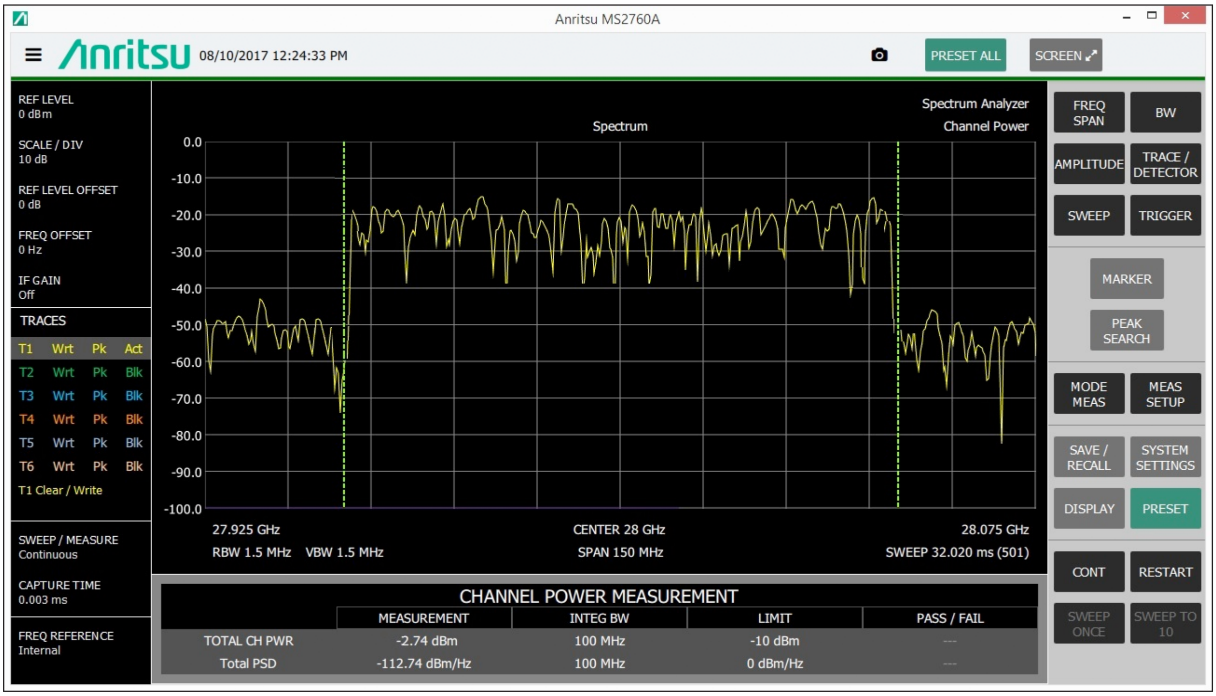
The Anritsu 5G mmWave coverage mapping solution consists of the following:

- Spectrum Master MS2760A 70 GHz Ultraportable Spectrum Analyzer
  - Windows® tablet to control the Spectrum Master MS2760A
- TRX NEON MA8100A Signal Mapper which consists of the following:
  - NEON Tracking Unit
  - NEON Signal Mapper Software Loaded onto an Android device
  - NEON Command Software for Microsoft Windows computers
  - NEON Cloud Service
- High Gain Antenna (for this application note we used a Horn Antenna)

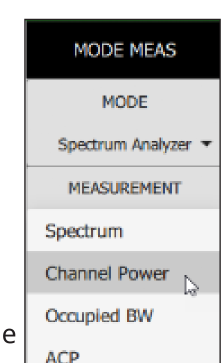
The TRX NEON Tracking Unit supports collection and processing of sensor data that delivers 3D location information. The TRX NEON Signal Mapper Application provides an intuitive Android user interface enabling lightly trained users to map signal and sensor information within buildings; users can initialize their location, start/stop mapping, and upload/ download mapping data to/from the cloud. The TRX NEON Command Software enables creation and visualization of 3D building maps, and provides centralized access to the TRX NEON Cloud Service to access stored maps and measurement data.

## Setting Up the Spectrum Master MS2760A for Channel Power Measurement

Prior to conducting a coverage mapping session, the Spectrum Master MS2760A spectrum analyzer must first be configured to properly measure the signals of interest. Knowledge of various parameters, such as anticipated signal strength and variation, potential presence of interfering signals, and noise sources, should be used in determining analyzer settings. A brief summary of the main analyzer setups is shown below. However, the user may want to refer to the Spectrum Master MS2760A User Guide (Anritsu document number 10580-00427) for more detailed guidance.

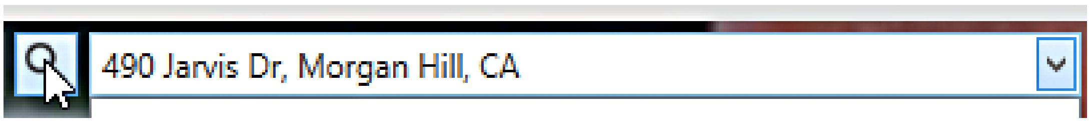



1. Connect the Spectrum Master MS2760A to the Windows tablet and start the Spectrum Master MS2760A Software
2. Frequency
   a. Set frequency to be measured as the spectrum analyzer center frequency.
3. Span
   a. Set the span to an appropriate setting for the desired signal to be measured.
4. Reference Level
   a. Reference Level: Input signal levels are referenced to the top line of the graticule, known as the reference level. Depending on the amount of power anticipated in the signals to be measured, the reference level should be adjusted accordingly.
   b. If gain ON: to bring signals out of the noise floor.
5. Detector Type
   a. Various detection circuits can be utilized. These include Peak, RMS/Average, and Negative. We recommend use of the Peak detector for indoor coverage mapping.
6. External Filtering
   a. Filtering should be used to measure signals in the presence of interferers. Filters can be added to the input of the analyzer to discriminate between wanted and unwanted signals, and avoid corruption of the measurement with adjacent high level signals.
7. Measurement Mode
   a. The TRX NEON MA8100A Signal Mapper application (run on an Android device) accepts channel power measurements from the Spectrum Master MS2760A. To setup channel power measurements press “MODE MEAS”, “MEASUREMENT”, and select “Channel Power”. The appropriate channel width will need to be entered. The Android device display will show the measurement values as they are taken.

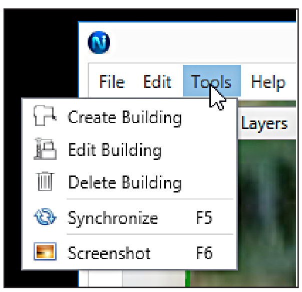


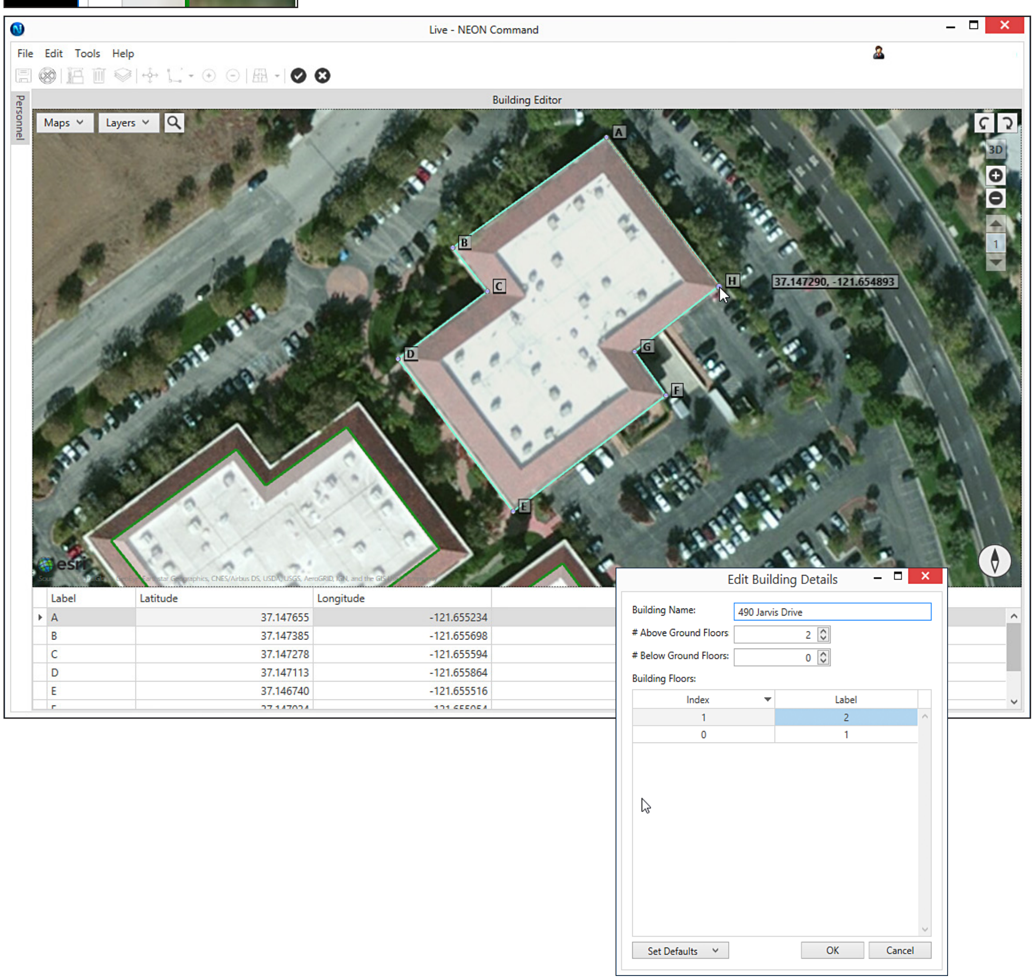
## Preparing an Indoor Map with the TRX NEON Command Software


1. On a Windows PC, open the TRX NEON Command software and navigate to the building or site that you want to map.
   a. Click the search icon located on the top right corner of the map.
   b. When a text input box appears, enter the address of the location that you wish to map.
   c. Press Enter to validate the address.

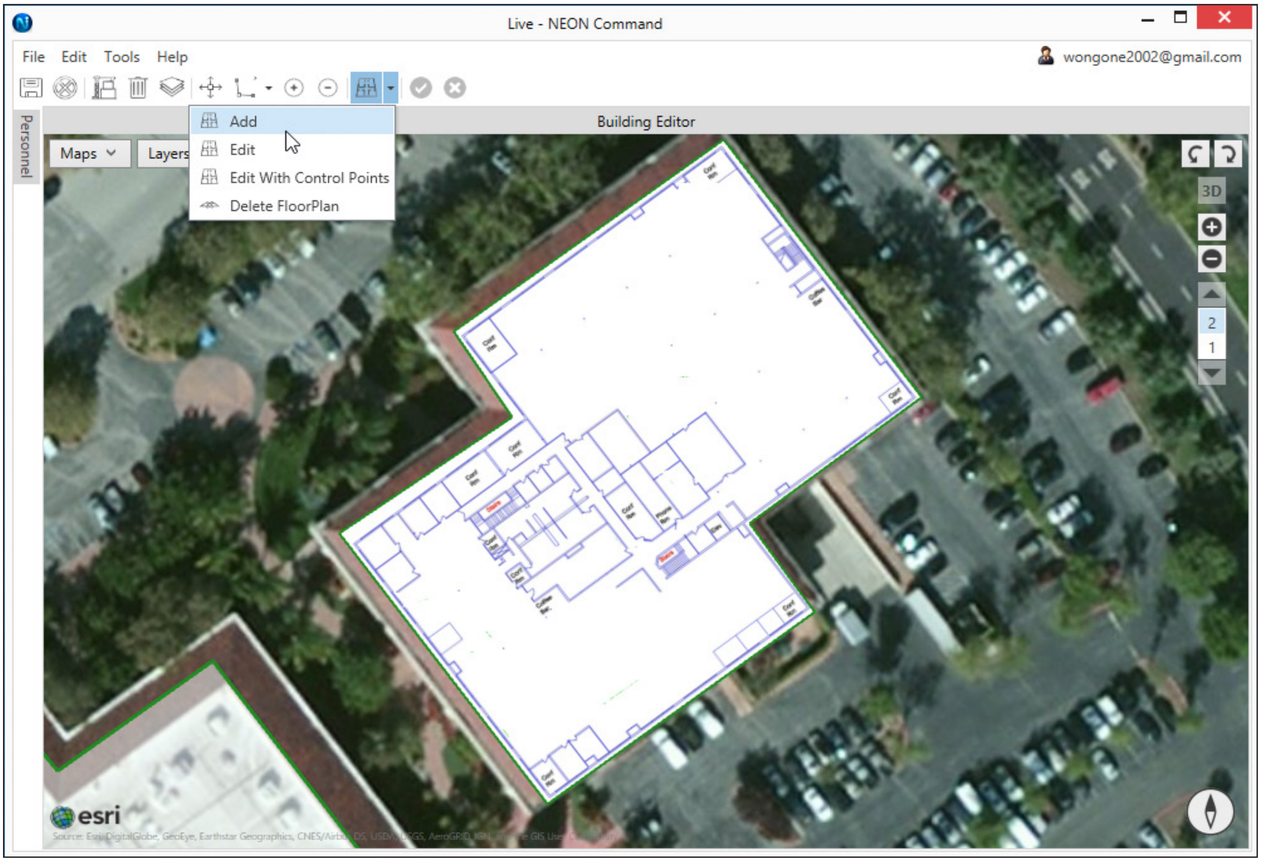



   d. If successful, the map will be centered on the given location.
   e. You can drag and zoom using the mouse to move around the map.
2. From the tools menu, select “Create Building” and draw the outline of the building you wish to map and fill in all the building details (i.e., number of floors, floor height).



3. Floor plans for each floor of the building should be located and converted to a graphics format (i.e., jpg, bmp, gif, etc.) format.
4. For each floor of the building, import the corresponding floor plan.

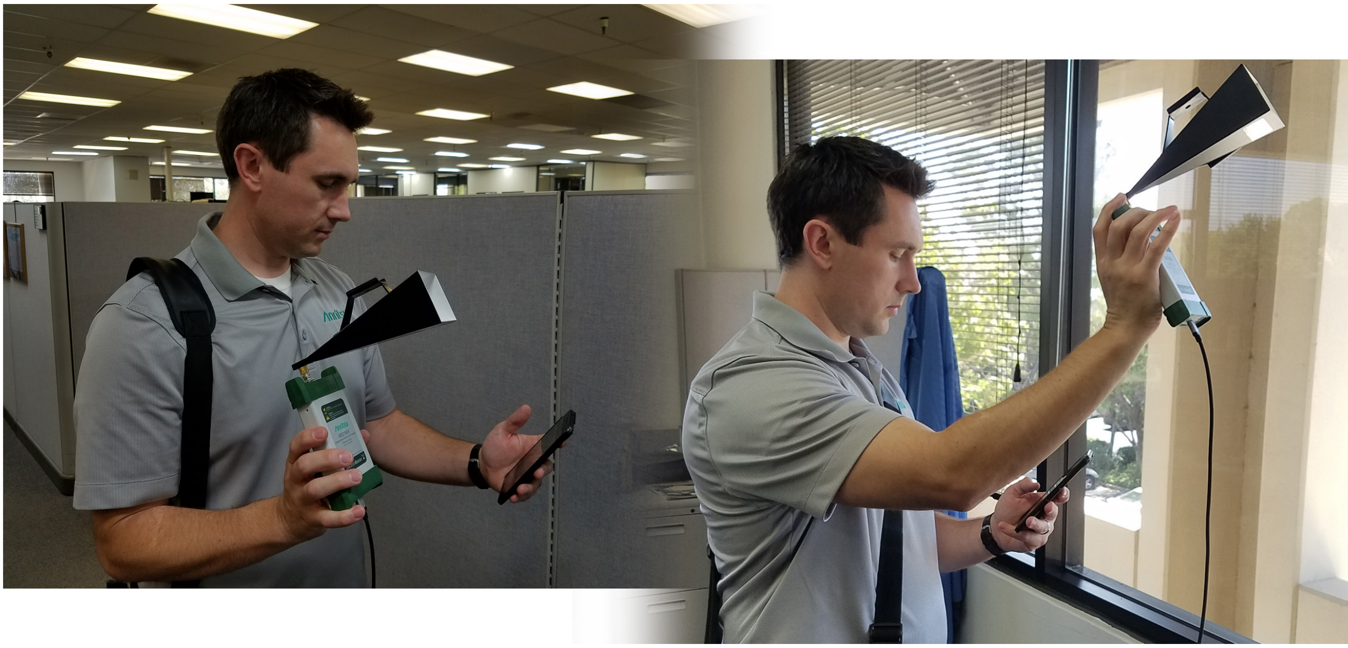



5. When finished, save the building. You are now ready to perform an indoor coverage mapping session on this building.

## Connecting the Spectrum Master MS2760A With a Measurement Antenna and the Android Device

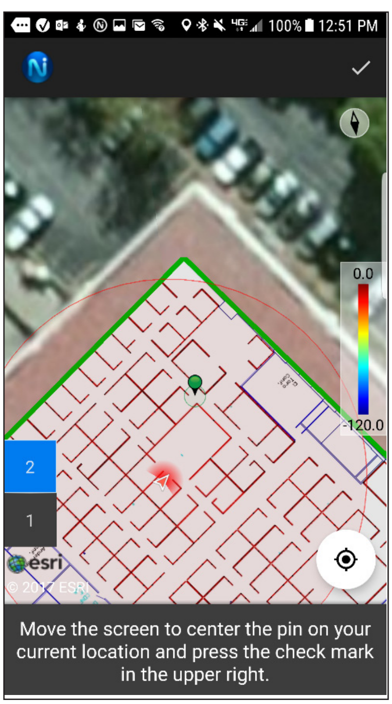
1. The next step is to connect the Spectrum Master MS2760A to a suitable measurement antenna with sufficient gain for the measurements you wish to perform.
2. The Spectrum Master MS2760A should already be set to measure the signal strength on the proper frequency.
3. Start the NEON Signal Mapper application on the Android Device.
4. The NEON Tracking Unit should be associated with the Android smart phone or tablet.
5. The Android device needs be attached to the Spectrum Master MS2760A via WiFi connection. In order for this to occur, both the Android device and the Spectrum Master MS2760A must be on the same network and subnet.
   a. Enter the Spectrum Master MS2760A IP Address in the Android Signal Mapper application with the Signal Mapper Settings menu.

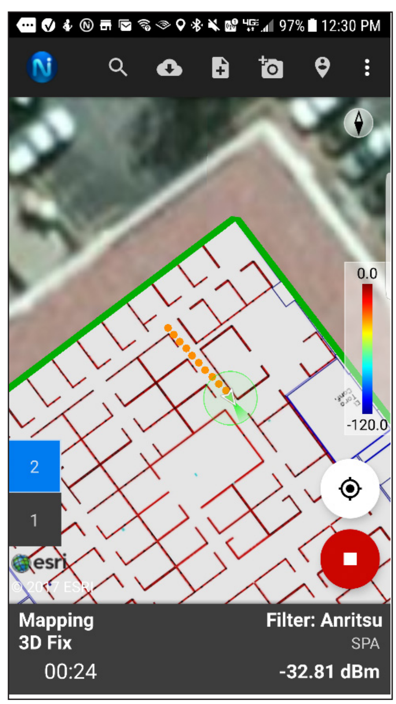
## Making Measurements



1. The first step is to initialize and calibrate the tracking unit. To do so, follow the location calibration procedures shown on the Android smart phone or tablet.

2. After calibration, you can now walk at a normal pace following your specified walking plan observing the location on the smart phone or tablet. The system will automatically collect the measurement and location information.




3. When the walk is complete, measurement results with location information can be uploaded to the included TRX NEON cloud storage or saved locally on the smart phone or tablet.

4. The measurement results can be reviewed using the TRX NEON Command Software in 2D, 3D, or as comma separated files with results for each measurement. The TRX NEON Command Software provides a heat map display which uses an average of the measurements made to predict coverage around the walking path.

## Summary

The ability to capture and analyze wide bandwidth, high frequency signals with advance beam forming and polarization schemes of 5G systems will present real challenges. New test equipment will need to be used. Engineers and technicians will need to be trained. The telecom industry and academic researchers are still in relatively early phases of understanding the millimeter-wave channel environment. Good models are still needed for the various environments that will need to be covered, such as urban, suburban, and multi-family dwelling units.

To support the rapidly growing demand for high-speed data, the U.S. FCC opened up nearly 11 GHz of spectrum in the mmWave frequency range (specifically: 27.5-28.35 GHz, 37-38.6 GHz, 38.6-40 GHz, and 64-71 GHz). While these new spectrum bands have paved the way for the development of new 5G technologies and services, radio frequency (RF) signals react to the environment differently at these ranges. For example, outdoor mmWave signals can be significantly attenuated by factors such as rain or foliage, while indoor mmWave signals are much more affected by office and cubicle walls.


Users will continue to expect improved service and functionality with these new 5G offerings - all at equal or lower prices. To ensure service levels are maintained cost effectively, coverage mapping is now more critical than ever before. Anritsu has shattered the cost and size barriers of mmWave instrumentation by offering its Spectrum Master MS2760A Ultraportable Spectrum Analyzer with TRX NEON MA8100A Signal Mapper.

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Specifications are subject to change without notice.


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