VIAVI Solutions

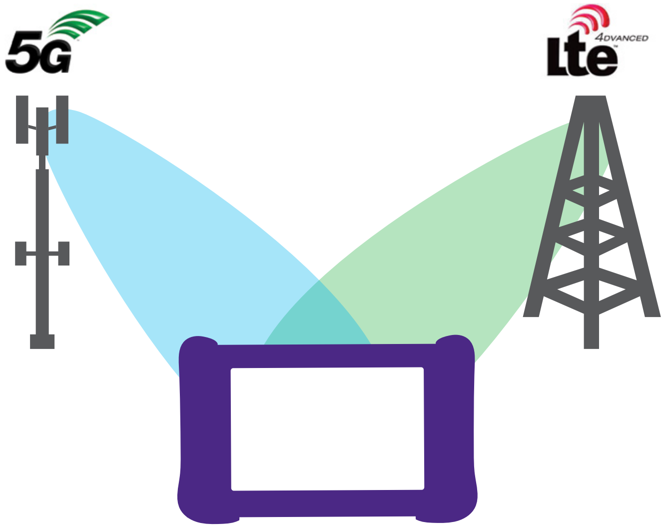
Application Note

VIAVI OneAdvisor-800 4G-LTE and 5G-NR Signal Analysis

VIAVI OneAdvisor is the ideal field test solution for 4G & 5G radio access networks, performing a comprehensive tests suite for an effective maintenance and optimization of the radio access network.

The radio access characteristics of 4G-LTE and 5G-NR technologies have some commonalities and interdependencies that allow the industry, including mobile operators and network element manufacturers, to have a gradual migration and evolution based on different applications.

An important commonality is the signal format, both technologies use orthogonal frequency division multiple access (OFDMA) transmission structure, which maximize the spectrum resources by allocating resource elements based on frequency and time.



OneAdvisor 4G & 5G Analysis

Benefits of OneAdvisor 4G LTE Analyzer

- LTE channel scanner to verify carrier aggregation verification, and ID scanner to assess power and pilot pollution
- MIMO performance and carrier's frequency and time variation.

Benefits of OneAdvisor 5G NR Analyzer

- 5G carrier scanner with cell identification and modulation quality
- 5G beam analysis assessing the power profile of the top 8 beams

Benefits of OneAdvisor DSS Analyzer

- Concurrent multi-carrier 4G and 5G analysis including cell identification, channel and pilot power and modulation quality

OneAdvisor 4G & 5G Analysis: All-in-one 5G and LTE test solution offers the best total cost of ownership.

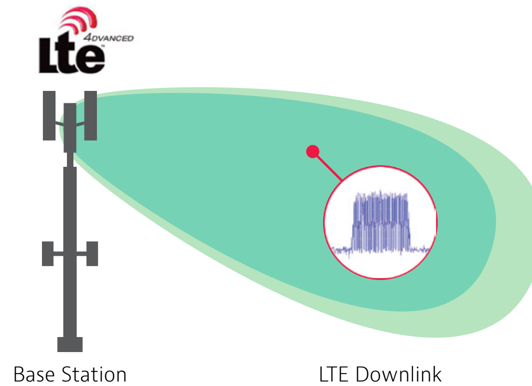
Having the same OFDMA signal structure created opportunities of inclusion of 5G-NR into a well-established 4G-LTE network, which is the case of Dynamic Spectrum Sharing (DSS) where conventional 4G-LTE channels can also transmit 5G-NR data sharing resource block in frequency and/or time.

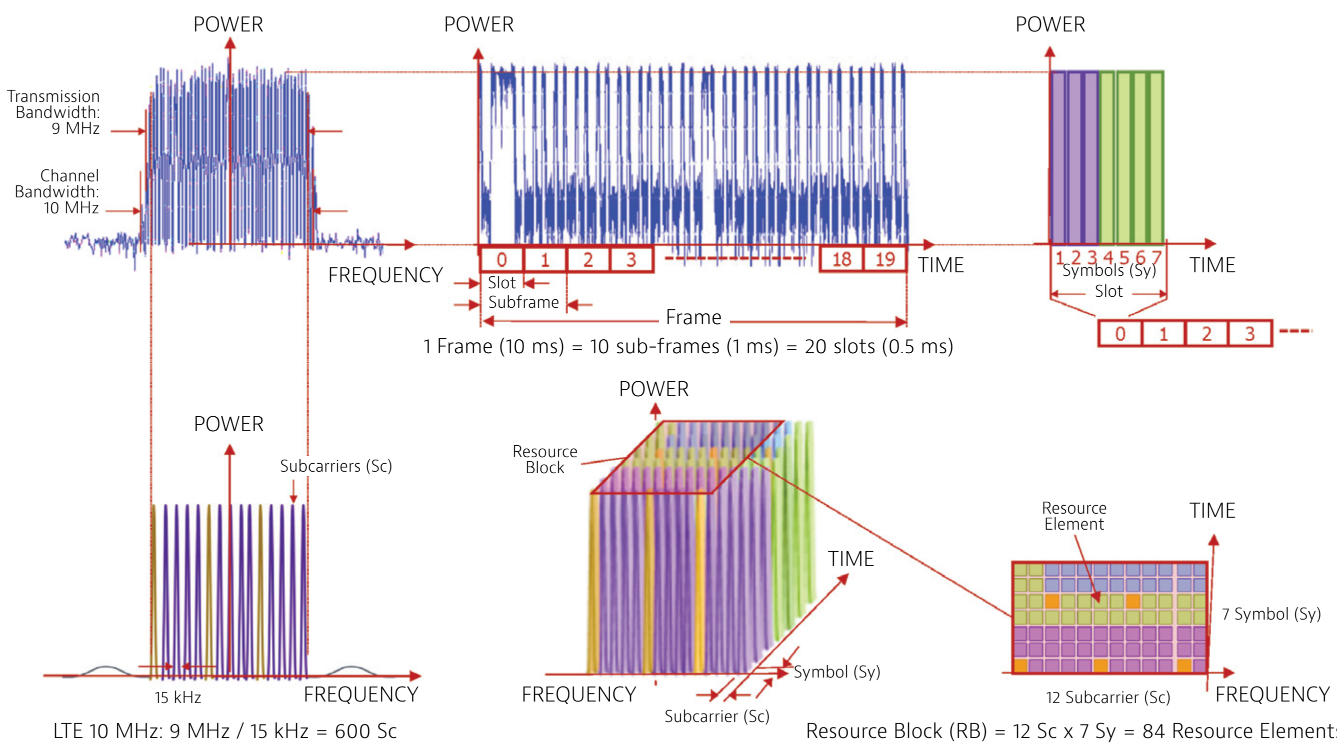
Similarly, is the case of initial 5G-NR deployments that needed dual connectivity or in non-standalone operation, establishing all the user equipment (UE) control signaling through a 4G-LTE channel and UE data traffic through a different 5G-NR channel.

4G-LTE-FDD and 4G-LTE-TDD Signal Analysis

Long-Term Evolution (LTE) technology incorporated a more efficient transmission model based on orthogonal frequency division multiple access (OFDMA) which utilize spectrum resources more efficiently.

LTE allocates resources in frequency (sub-carriers) and time (symbols) defining the transmission of user channels in resource blocks (12 subcarriers x 7 symbols).





LTE Signal Format (OFDMA)

In addition, 3GPP defined six channel bandwidths for LTE, with their corresponding resource blocks, subcarriers and transmission bandwidths, as follows:

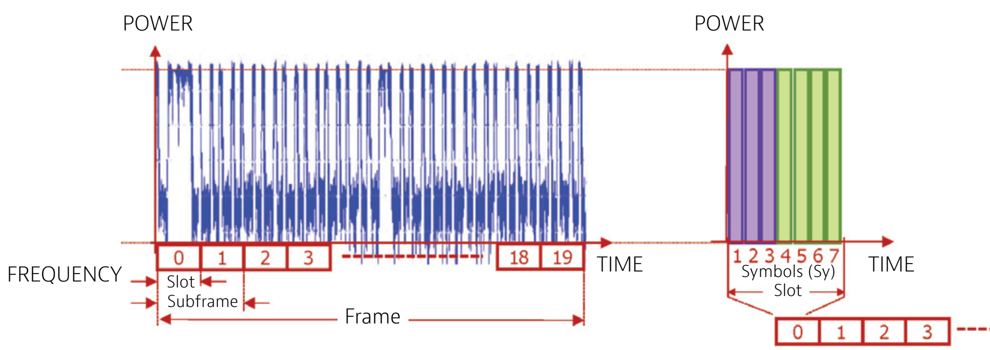
Channel Bandwidth (MHz)	1.4	3	5	10	15	20
Transmission Bandwidth (RB)	6	15	25	50	75	100
Transmission Bandwidth (Sc)	72	180	300	600	900	1,200
Transmission Bandwidth (MHz)	1.08	2.7	4.5	9	13.5	18

LTE transmission is done in frames with a duration of 10ms, composed of 10 subframes of 1ms. There are different frame structures defined for radio transmission, including:

- LTE-FDD: Frequency Division Duplex
- LTE-TDD: Time Division Duplex
- LTE-LAA: Licensed Assisted Access

LTE-FDD Structure

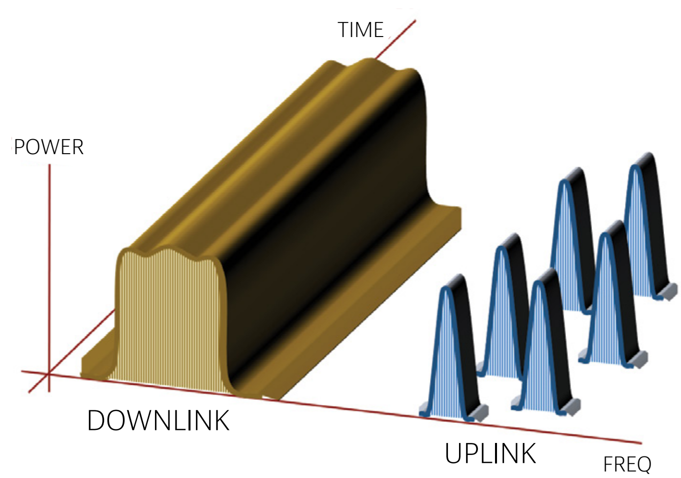
LTE-FDD transmission is done in 10ms frames containing 10 sub-frames of 1ms and 20 slots of 0.5ms, each slot is composed of 7 symbols (normal cyclic prefix), therefore a resource block of (12 subcarriers by 7 symbols) occupies one slot



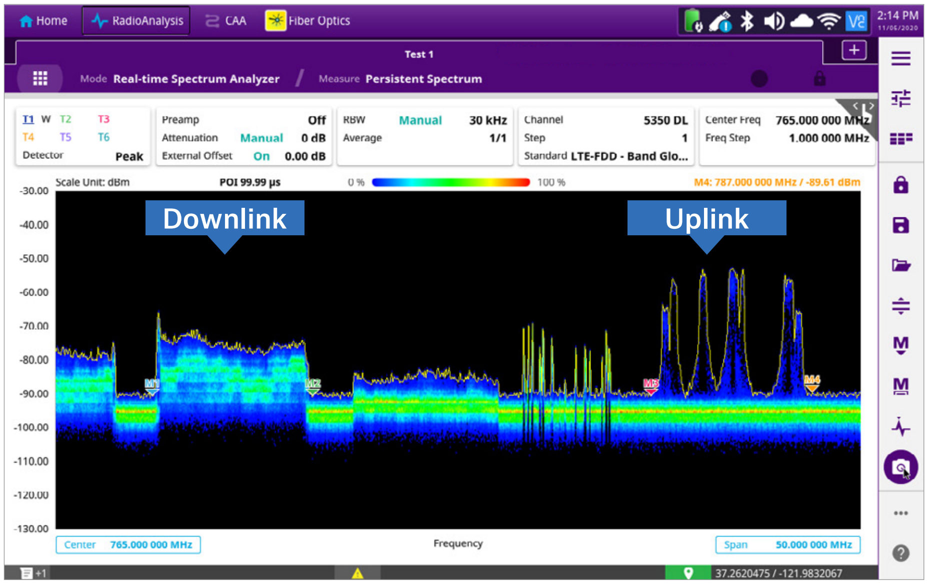
1 Frame (10 ms) = 10 sub-frames (1 ms) = 20 slots (0.5 ms)

LTE-FDD Frame Structure

The main attribute of LTE-FDD signals is its duplex transmission mode which is based on frequency where the base station is transmitting (downlink) at a different frequency than the transmission of the user equipment (uplink).



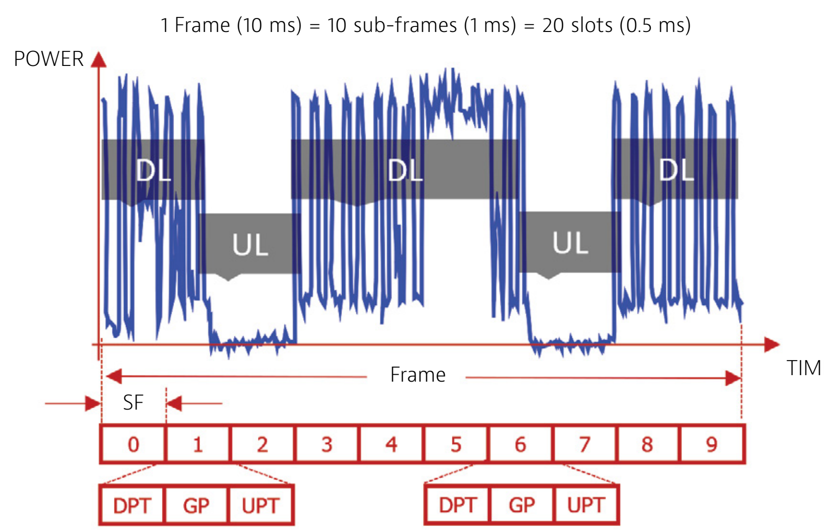
LTE-FDD Downlink and Uplink



OneAdvisor Realtime Spectrum – LTE-FDD

LTE-TDD Structure

LTE-TDD transmission is done in 10ms frames containing 10 sub-frames of 1ms and 20 slots of 0.5ms, each slot is composed of 7 symbols (normal cyclic prefix), therefore a resource block of 12 subcarriers by 7 symbols occupies one slot.



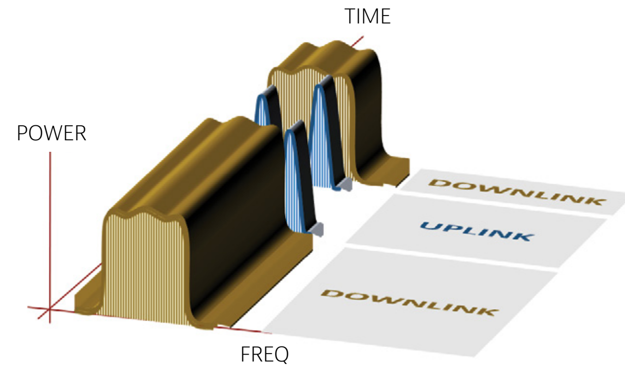
DPT: Downlink Pilot Timeslot | UPT: Uplink Pilot Timeslot | GP: Guard Period

LTE-TDD Frame Structure

The main attribute of LTE-TDD is that radio (downlink) transmission and user equipment (uplink) transmission take place at the same frequency, but at different timeslot (sub-frame).

There are three special fields:

- Downlink pilot timeslot
- Guard period
- Uplink pilot timeslot



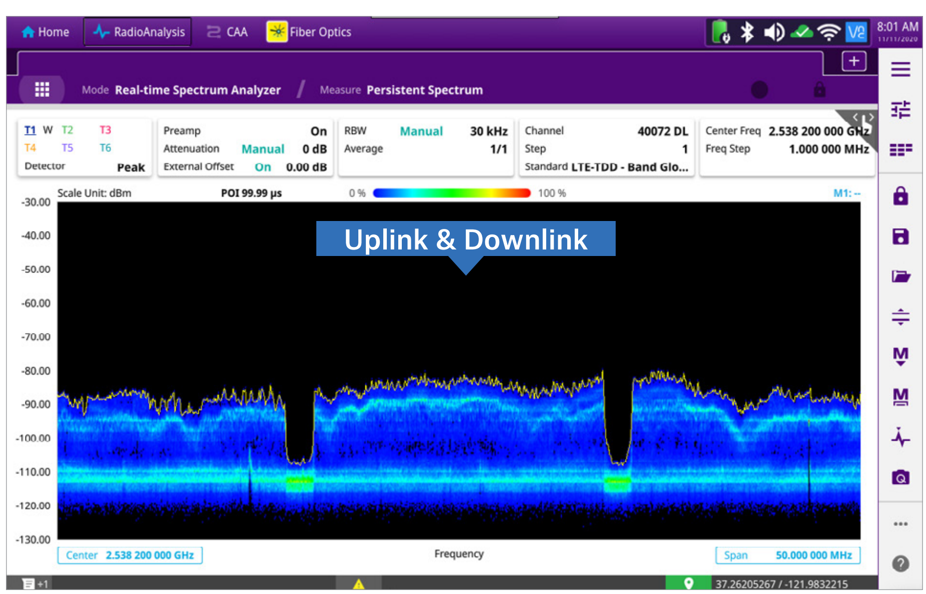
LTE-TDD Downlink and Uplink

LTE-TDD frame can be set to different configurations of uplink and downlink:

Config	Periodicity	SF 0	SF 1	SF 3	SF 3	SF 4	SF 5	SF 6	SF 7	SF 8	SF 9
0	5ms	D	S	U	U	U	D	S	U	U	U
1	5ms	D	S	U	U	D	D	S	U	U	D
2	5ms	D	S	U	D	D	D	S	U	D	D
3	10ms	D	S	U	U	U	D	D	D	D	D
4	10ms	D	S	U	U	D	D	D	D	D	D
5	10ms	D	S	U	D	D	D	D	D	D	D
6	10ms	D	S	U	U	U	D	S	U	U	D

U: Uplink Subframe | D: Downlink Subframe | S: Special Subframe

LTE-TDD Downlink and Uplink Frame Allocation



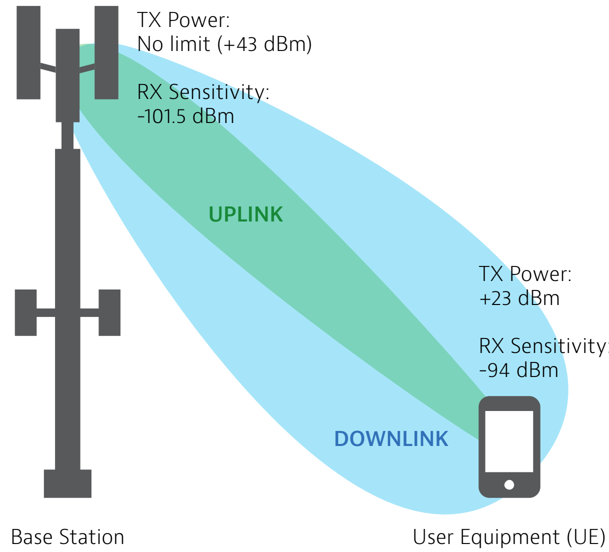
OneAdvisor Realtime Spectrum – LTE-TDD

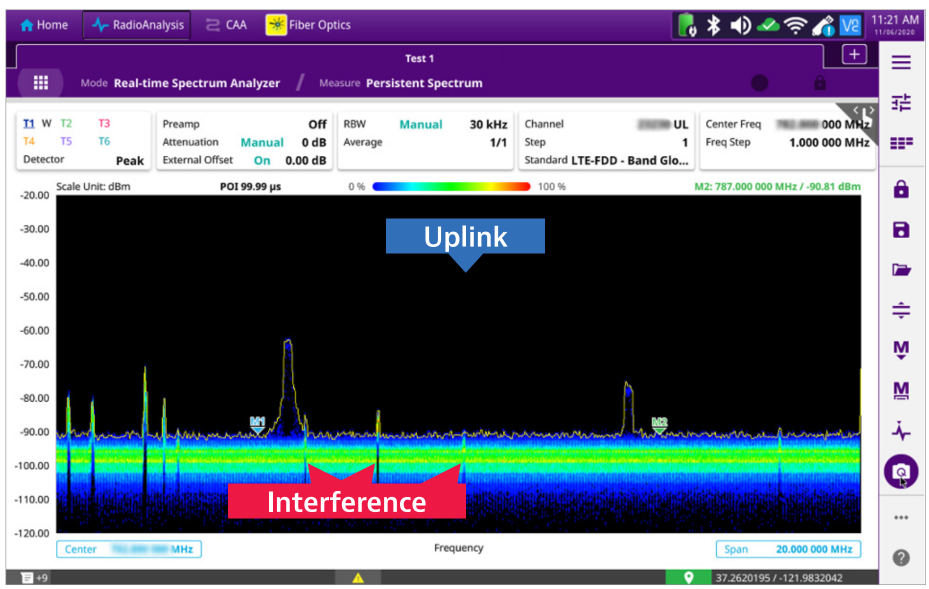
Interference Analysis in LTE-FDD and LTE-TDD

Interference affects all wireless communication systems, and particularly the user equipment (UE) is more susceptible to interference impairments since its transmission power is significantly lower than the base station's.

Therefore, any interfering signal in the uplink, even transmitting at a low power level, can cause retransmissions or call drops, ultimately degrading mobility services.

For LTE-FDD radio access the process of detecting uplink interference is straightforward because the uplink has a defined frequency range dedicated for UE transmission.

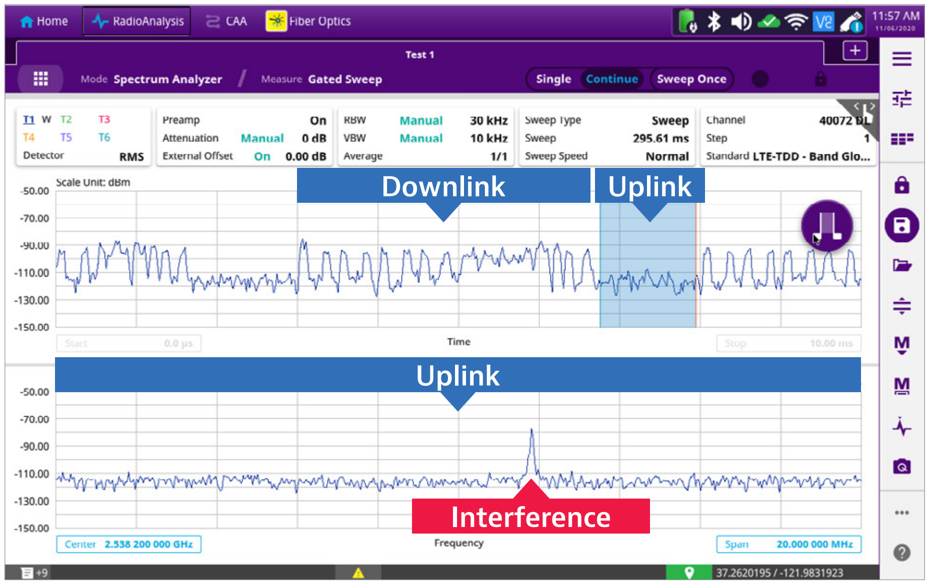




OneAdvisor Realtime Spectrum – LTE FDD Uplink

In the case of LTE-TDD radio access the process of detecting uplink interference is more complex since the downlink and uplink are being transmitted at the same frequency, therefore the downlink power might be masking interference signals at lower power level making them difficult to detect but still negatively affecting the uplink transmission.

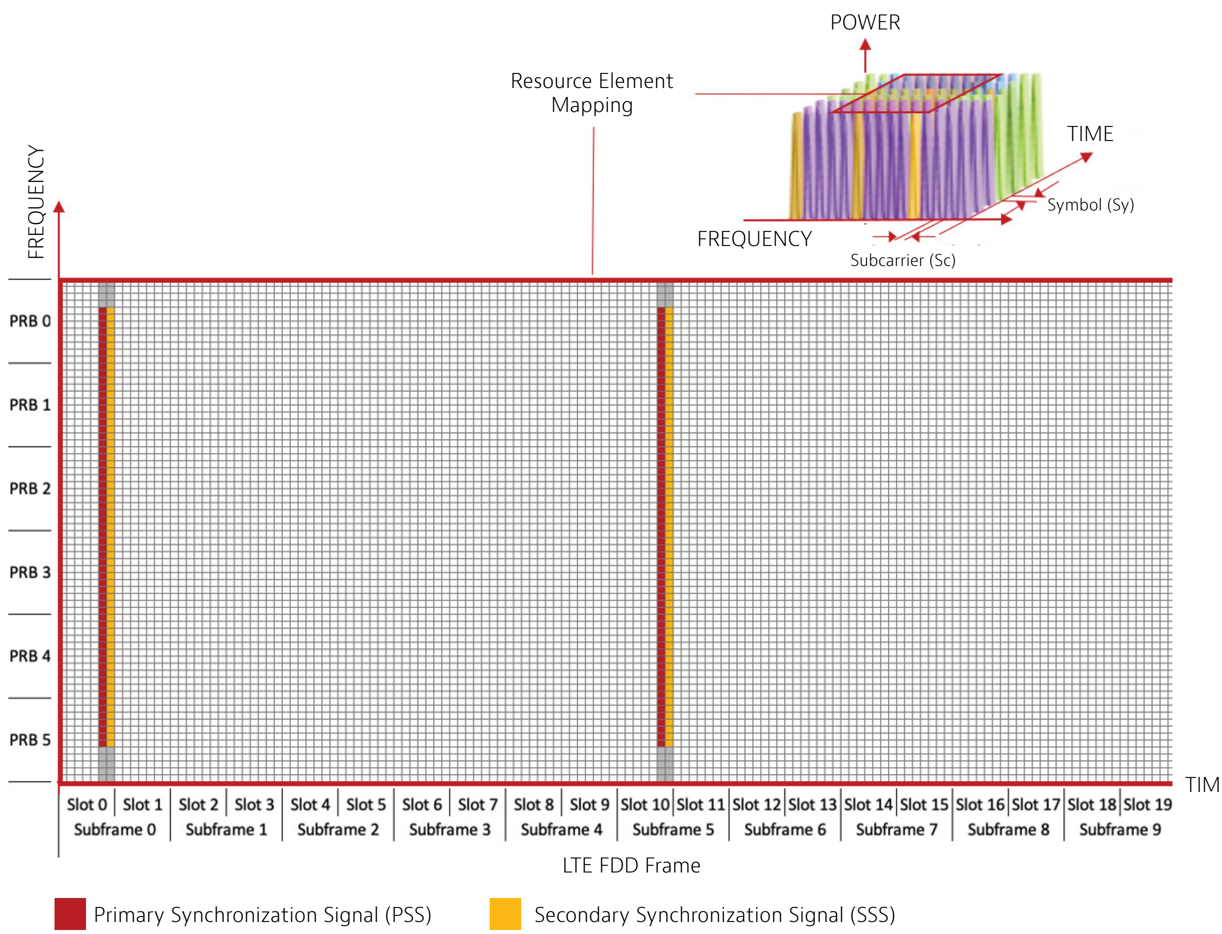
The most effective methodology to detect interference in LTE-TDD radio access is with gated spectrum, conducting spectrum measurements only in the transmission time of the uplink.



OneAdvisor Gated Sweep – LTE-TDD Interference

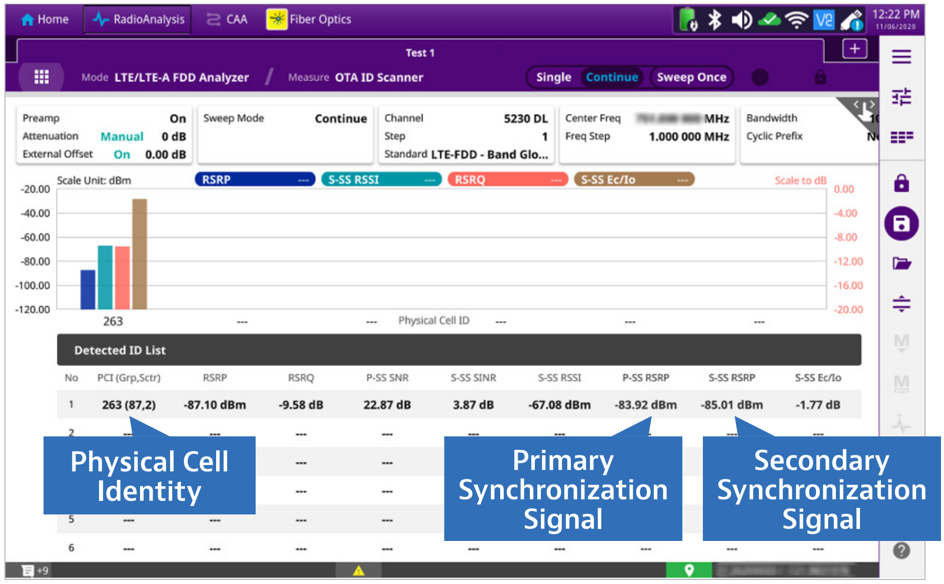
LTE Synchronization and Reference Signals

LTE synchronization signals play a critical role to establish a connection between UEs and base stations, the communication starts by the UE performing a cell search process and acquiring the time and frequency synchronization of the base station and deriving the cell identity.



LTE FDD Frame with Synchronization Signals

There are two types of synchronization signals, the primary synchronization signal (PSS) and the secondary synchronization signal (SSS), which are constantly transmitted by the base station in the first and sixth subframe.

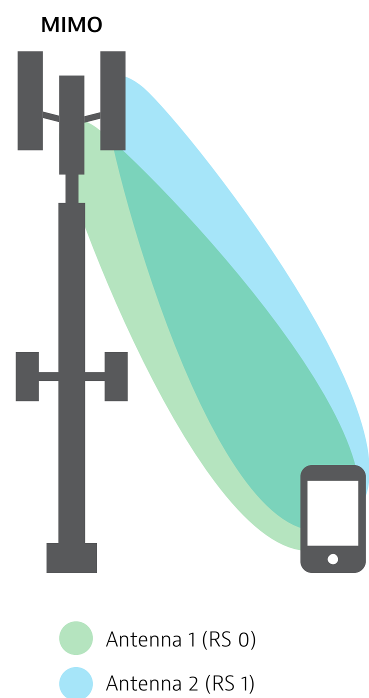


OneAdvisor LTE Signal Analysis – PSS, SSS and Cell Identity

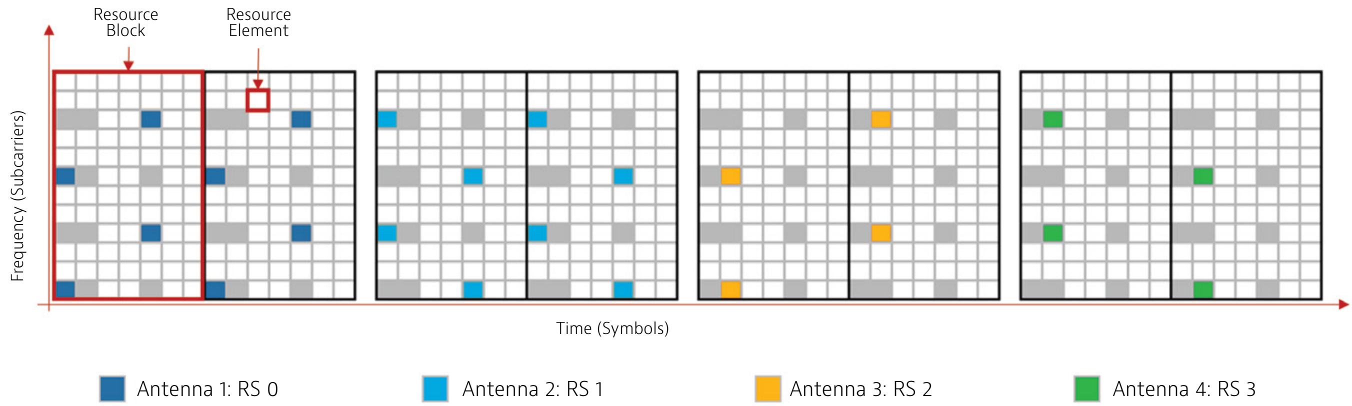
LTE reference signals are constantly transmitted to determine the antenna transmission of LTE multiple input multiple output (MIMO) that creates multiple communication layers for the purpose of increasing coverage or capacity.

The UE can decode those MIMO layers based on the signal quality from each antenna (RS0 to RS7), and providing an indication of the RF environment to the base station from which it derives the communication mode assigned to that particular UE:

- Spatial Multiplexing, increases capacity by transmitting different user data streams from multiple antennas, creating a parallel communication channels or layers, increasing bandwidth utilization.
- Diversity, increases coverage by transmitting the same user data stream from multiple antennas, providing better reception in environments with high multipath and fading.

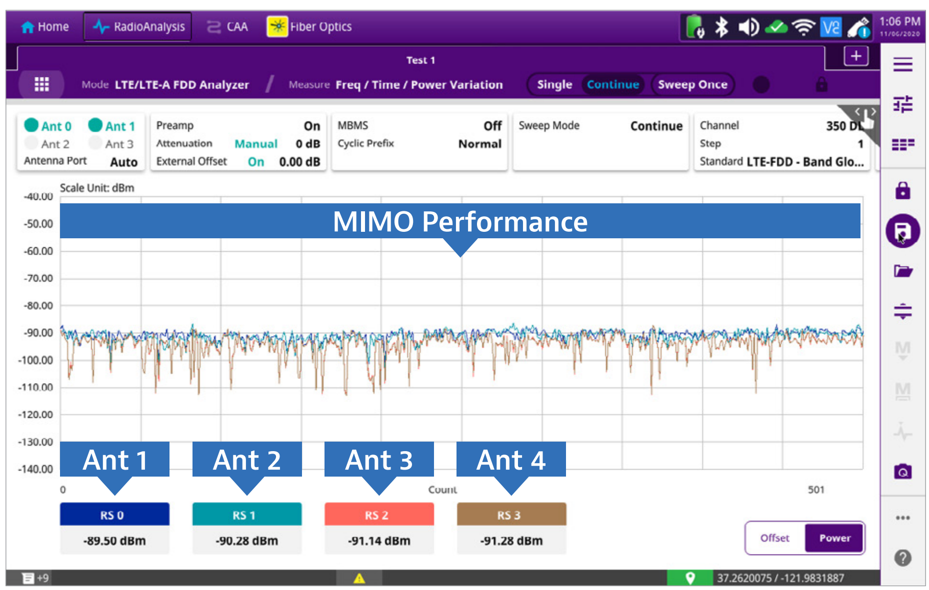


LTE MIMO 2x



LTE Reference Signals (Antennas 1 to 4)

For either transmission mode, it is essential that the base station is transmitting at a similar power level from its antennas (2x, 4x, or 8x) to achieve either coverage or capacity. A power significant gap between antennas will inhibit the benefits of MIMO



OneAdvisor LTE Signal Analysis – MIMO Power

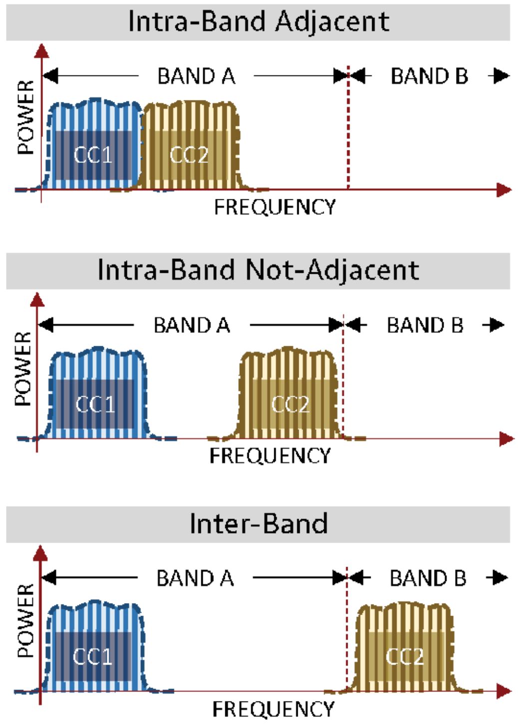
LTE Carrier Aggregation

LTE was also defined to utilize multiple carriers aggregating spectral resources with the purpose of increasing bandwidth to user equipment and improve customer experience.

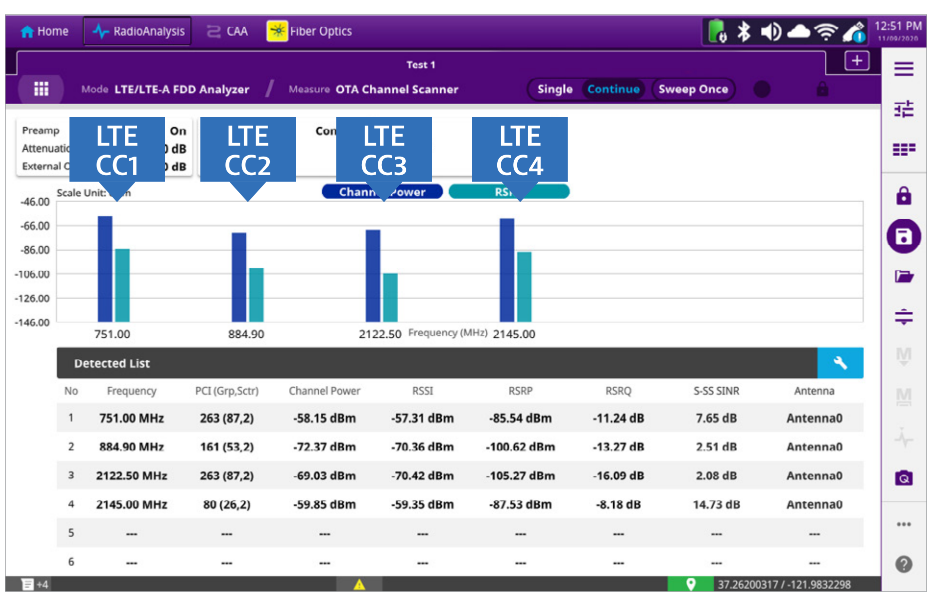
LTE carriers have maximum transmission bandwidth of 20MHz, and by aggregating multiple component carriers (CC) the transmission can increase up to 640MHz.

The component carrier that are aggregated can be allocated in three main configurations:

- Intra-Band Adjacent
- Intra-Band Not-Adjacent
- Inter-Band



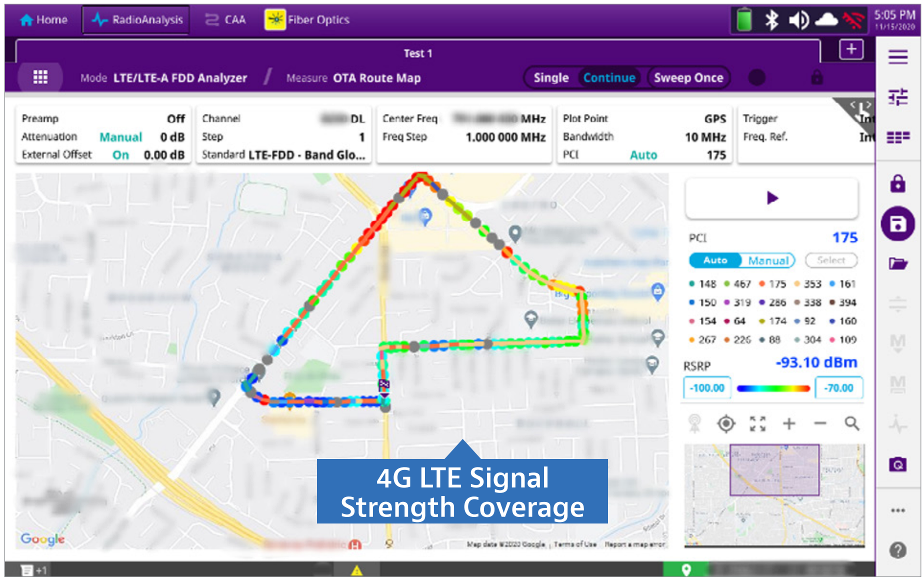
LTE Carrier Aggregation



OneAdvisor LTE Signal Analysis – Carrier Aggregation

LTE Coverage

Service availability is derived by signal coverage or power level of LTE pilot signals (synchronization and reference signals), not only to identify network dead-zones that will cause call drops, but also to identify areas where power levels are close to the UE sensitivity level that might degrade throughput and even cause retransmissions, negatively impacting customer experience.



OneAdvisor LTE Signal Analysis – Route Map

5G-NR Signal Analysis

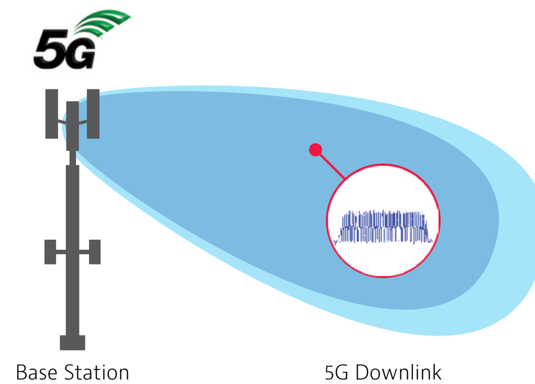
5G New Radio (NR) has been defined to provide an improved set of services and applications, including:

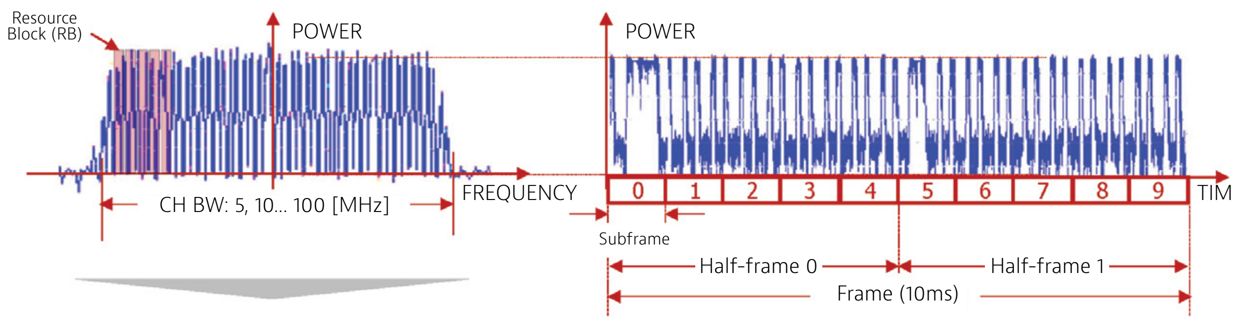
- Enhanced Mobile Broadband Services (eMBB), including ultra-high-definition display, 3D projections, immersive video, and augmented reality
- Enhanced Massive Machine Type Communication Services (mMTC), high density of machines connected to the network with different network requirements
- Ultra-Reliable and Low Latency Communication Services (URLLC), real-time applications including driverless cars, real-time traffic control, emergency and disaster response, e-health, and remote tactile control among others.

5G-NR radio access incorporates additional flexibility than LTE signal structure, including the following:

- Channel bandwidth: flexibility for wider channel bandwidth configurations; for example, for frequency range 1 (FR1) defined by 3GPP from 410MHz to 7125MHz the transmission bandwidth can have a range of 5MHz to 100MHz.

- OFDMA structure numerology: the signal frequency components or sub-carriers can be configured at different bandwidths including 15KHz, 30KHz, or 60KHz with a corresponding multiplier in time to allocate the number of symbols per frame.
- Beamforming: ability to generate and shape multiple beams based on phase and amplitude to direct radiated power to the user's serving area

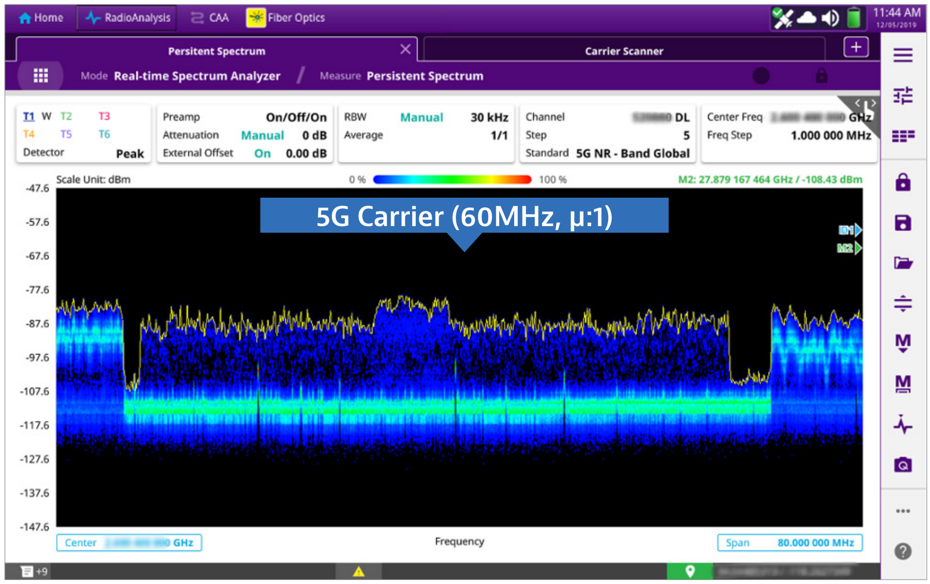




FR1: 450 MHz to 7.1 GHz (RB)														
µ	Δ*f*	5	10	15	20	25	30	40	50	60	70	80	90	100
0	15	25	52	79	106	133	160	216	270					
1	30	11	24	38	51	65	78	106	133	162	189	217	245	273
2	60		11	18	24	31	38	51	65	79	93	107	121	135

FR2: 24.25 GHz to 52.6 GHz (RB)					
µ	Δ*f*	50	100	200	400
2	60	66	132	264	
3	120	32	66	132	264

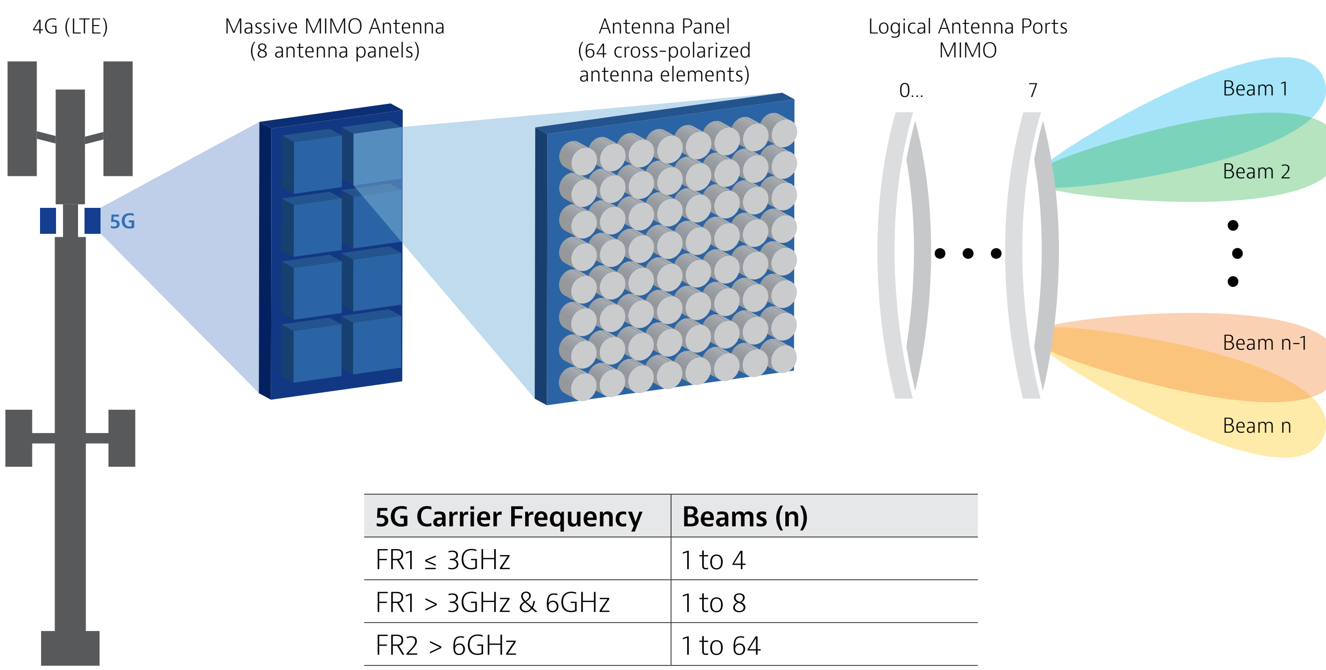
5G-NR Signal Data Structure and Numerology



OneAdvisor Realtime Spectrum – 5G FR1

5G-NR Beamforming

Beamforming is a distinctive property of 5G-NR with which multiple beams can be transmitted to user's equipment (UE) either mobile phones or customer premise equipment, to increase bandwidth and it is possible by increasing the number of antenna elements in the cell.

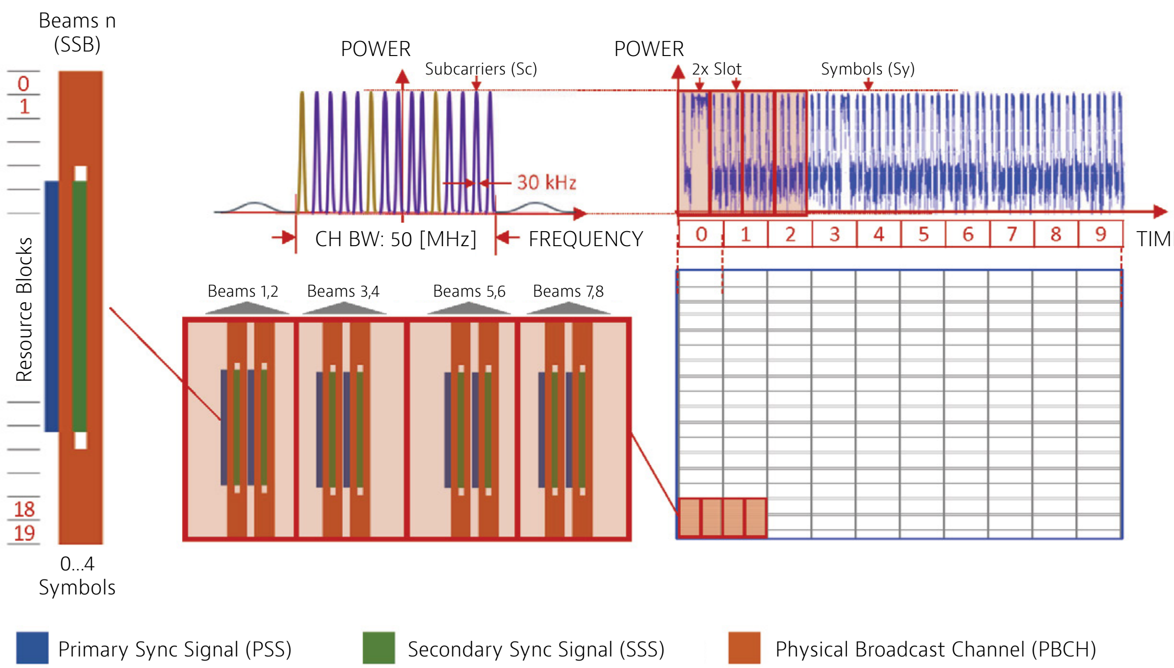


5G Carrier Frequency	Beams (n)
FR1 ≤ 3GHz	1 to 4
FR1 > 3GHz & 6GHz	1 to 8
FR2 > 6GHz	1 to 64

5G Massive MIMO and Beamforming

5G-NR cells transmitting at frequencies below 7GHz can be equipped with antennas containing a few tenths of antenna elements, limiting the number of beams that can be generated, 3GPP has defined a maximum of 4 coverage beams for frequencies up to 3GHz, and a maximum of 8 for frequencies up to 7GHz.

As transmission frequency increases, antenna elements get smaller, therefore 5G-NR cells transmitting at frequencies above 24GHz can be equipped with antennas containing several hundreds of antenna elements capable of transmitting up to 64 coverage beams.



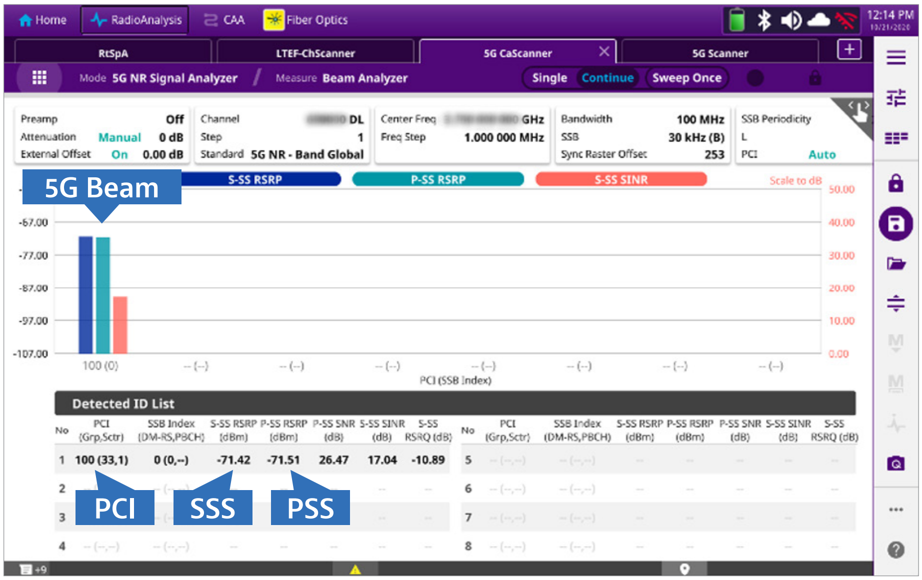
5G-NR coverage beams or Synchronization Signal and PBCH block (SSB) contain the following information required for devices to connect to the cell:

a. Primary Synchronization Signal (PSS)

b. Secondary Synchronization Signal (SSS)

c. Physical Broadcast Channel (PBCH)

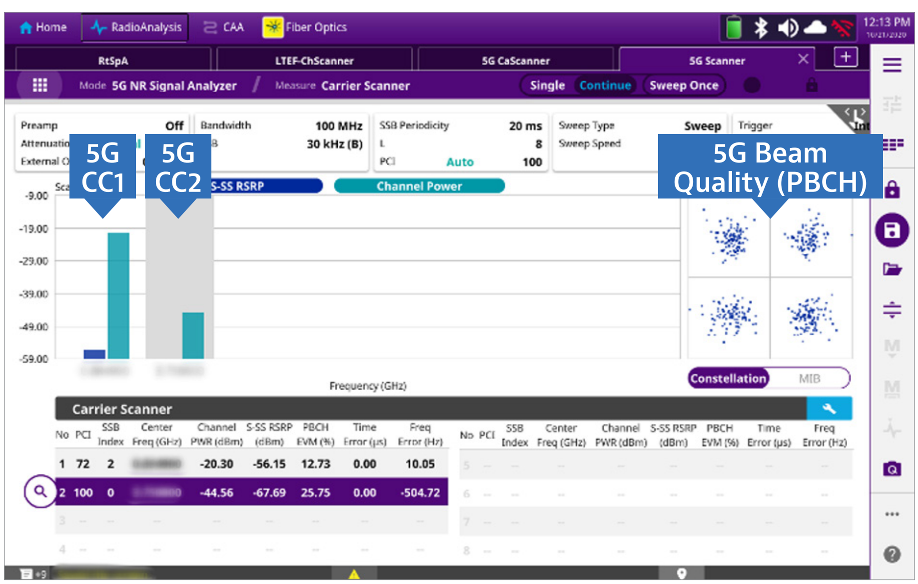
The UE's initiates its cell attachment by performing a cell search of beams or SSB's from which it will acquire synchronization and obtain the physical cell identity (PCI).



OneAdvisor 5G Analysis – Beam Analysis

5G-NR defines channel bandwidths up to 100MHz in FR1 and up to 400MHz in FR2, minimizing control channels and maximizing user data channels for wide spectrum; however, it also provides the flexibility to aggregate multiple carriers, including 2 component carriers in FR1 and 8 component carriers in FR2.

Beam power level is a relevant indicator for cell coverage, and beam quality is a relevant indicator for cell throughput.

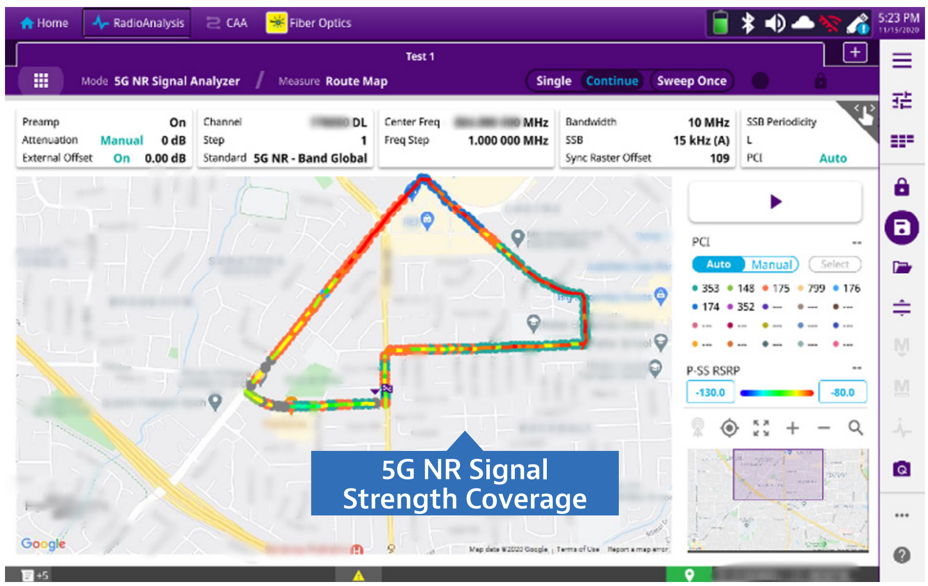


OneAdvisor 5G Analysis – Carrier Scanner

OneAdvisor 5G is the first field-portable test solution in the market that enables RF engineers to test, identify and rectify both 5G and LTE/LTE-A radio access issues with one easy-to-use solution.

5G Coverage

Service availability is derived by signal coverage or power level of 5G beam signals (SSB) verifying 3D beamforming by assessing beam availability horizontally and vertically, identifying network dead-zones that will cause call drops, but also to identify areas where beam power levels are close to the UE sensitivity level that might degrade throughput and even cause retransmissions, negatively impacting customer experience.



OneAdvisor 5G Signal Analysis – Route Map

Dynamic Spectrum Sharing (DSS)

DSS technology has been introduced by the industry to enable 5G services to be delivered in LTE networks to accelerate the availability of 5G services.

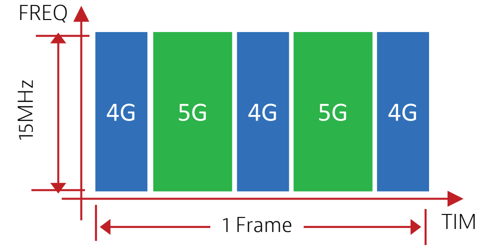
Traditionally mobile network operators had two main options to deploy new cellular technologies, spectrum re-farming or spectrum acquisition. DSS effectively creates a third option for mobile operators to deploy 5G-NR by reconfiguring 4G-LTE channels, without disrupting existing customers, and minimizing the implicit cost and extended time of spectrum re-farming and spectrum acquisition.

Spectrum can be shared between two different technologies in Time, Frequency or a combination of both, this is achieved more efficiently with 4G and 5G since they have an orthogonal signal format that can allocate spectrum resources in frequency and time.

Time Division Sharing

Time division sharing allocates different timeslots to different technologies, this is better realized with LTE and 5G since both have a frame time of 10ms with 10 subframes, and each sub-frame (1ms) can be allocated to LTE or 5G.

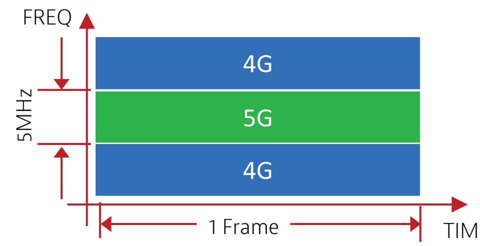
This methodology leverages the LTE multimedia broadband multicast services (MBMS) technology that permits different traffic types in LTE sub-frames, for example LTE and Broadcast, or LTE and 5G.



Frequency Division Sharing

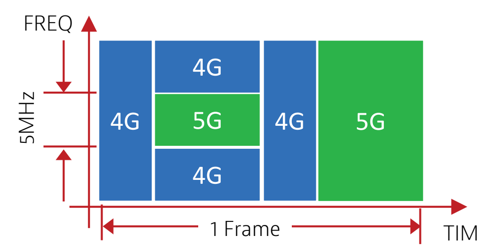
Frequency division sharing allocates different frequency parts to different technologies, for example, an LTE signal with a 15MHz bandwidth, can be partitioned in 3 bandwidth parts of 5MHz each, where LTE and 5G can be assigned independently for each bandwidth part.

The disadvantage of this methodology is that it is not as dynamic as time division sharing.



Time and Frequency Sharing

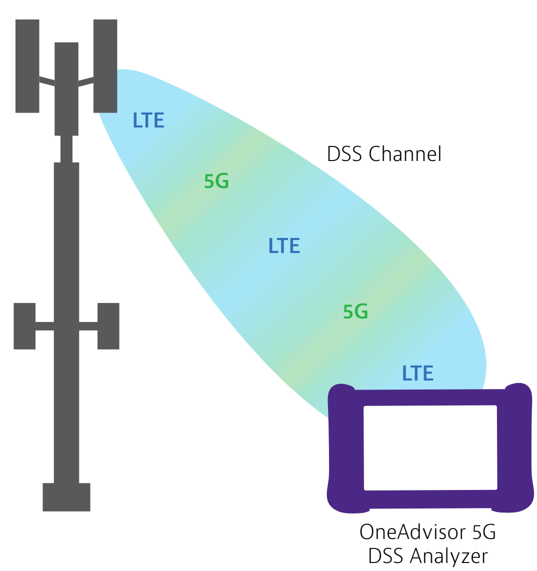
Time and frequency division sharing allocates spectrum resources in timeslots and bandwidth parts combining LTE and 5G; however, this methodology is more challenging to implement due to the complexity of signal processing and control channels required in radios and mobile devices.

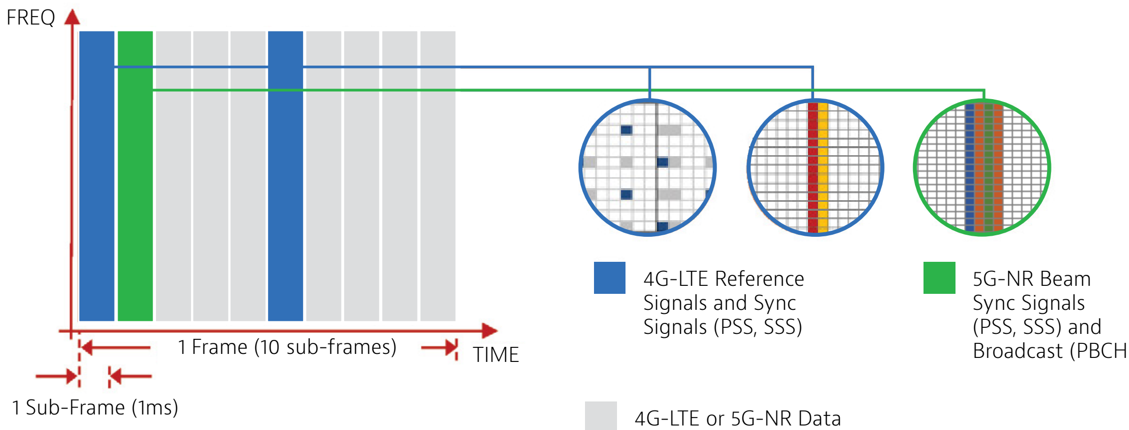


DSS Analysis

OneAdvisor DSS Analysis option mode offers the following concurrent 5G-NR and 4G-LTE measurements:

- DSS RF Analysis: channel power and occupied bandwidth.
- DSS OTA (over the air) Analysis: concurrent 5G and LTE channel scanner, ID scanner, control channel, frequency, time and power variation, and network coverage.



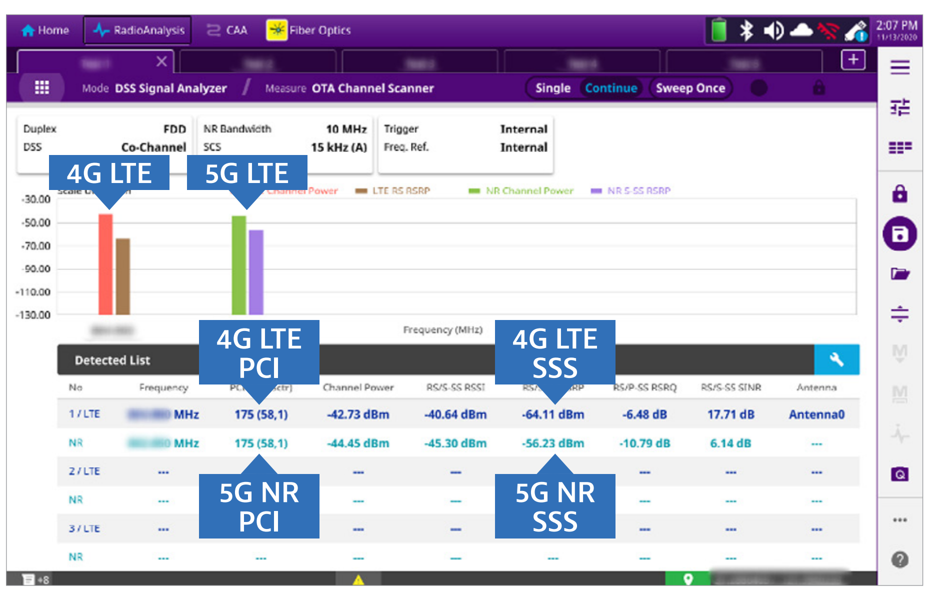


DSS TDD Frame – 4G-LTE and 5G-NR Pilot Signals

DSS Serving Sectors

The service sector is the radio that is transmitting at the highest power in a given location.

DSS serving sectors is characterized by the specific physical cell identity (PCI) and synchronization signals (SSS) of 4G-LTE and 5G-NR.



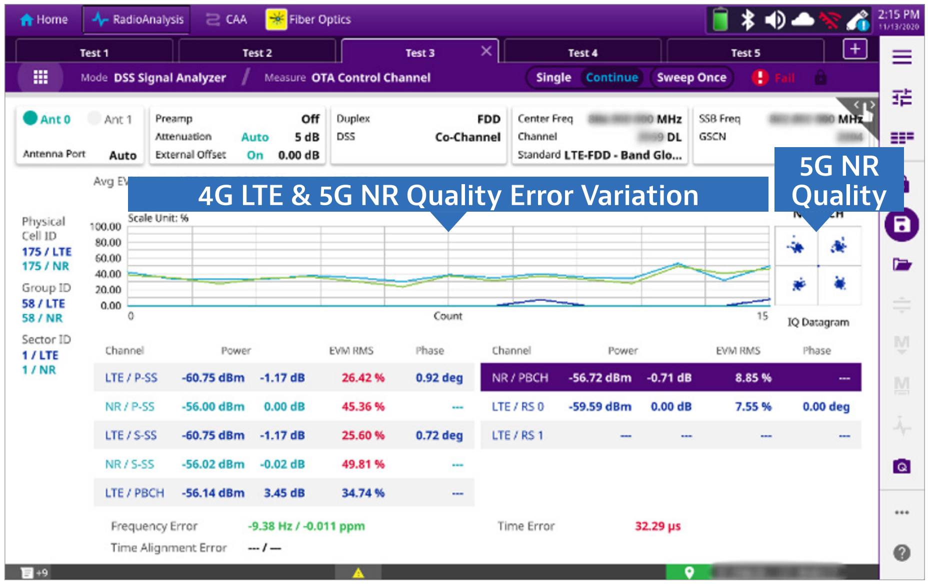
OneAdvisor DSS Signal Analysis – Channel Scanner

DSS Signal Quality

The signal quality is a viable representation of any distortion or noise in the pilot signal, which directly impacts service bandwidth and throughput.

DSS signal quality is measured by the error vector magnitude of the specific pilot signals, including:

- 4G-LTE: reference signals, synchronization signals (PSS & SSS), and broadcast channel (PBCH)
- 5G-NR: synchronization signals (PSS & SSS), and broadcast channel (PBCH)

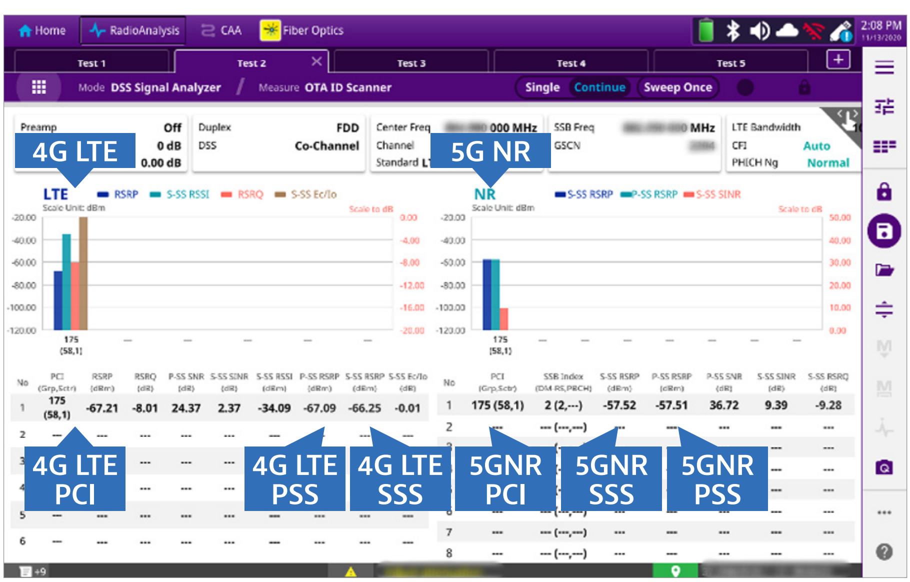


OneAdvisor DSS Signal Analysis – Control Channel

DSS Adjacent Sector

Availability of adjacent sectors allow smooth or soft-handover for mobile user equipment, avoiding call drops; however, an excessive number of sectors present might cause increased noise level or pilot pollution.

DSS adjacent sectors is represented by the specific physical cell identity (PCI) and synchronization signals (PSS & SSS) of multiple 4G-LTE and 5G-NR sectors.



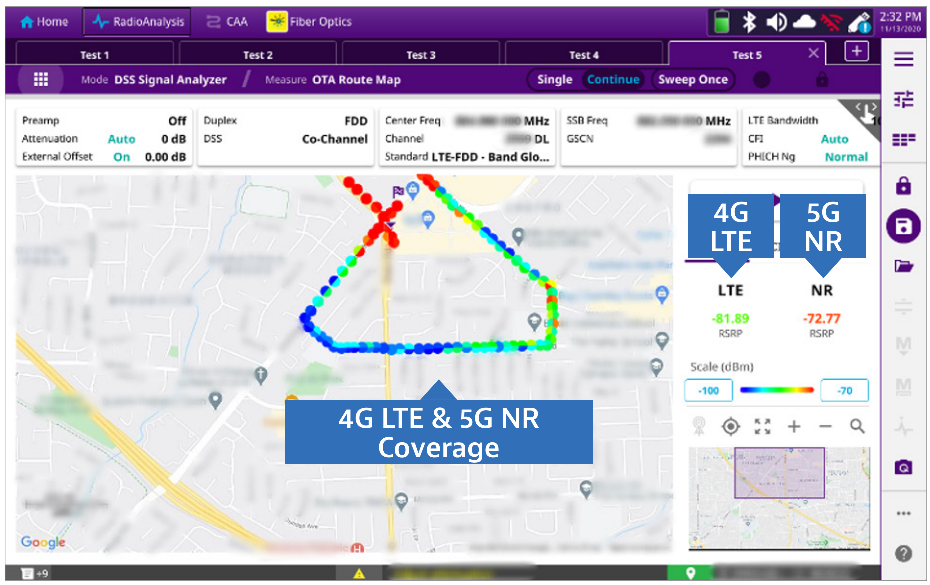
OneAdvisor DSS Signal Analysis – OTA ID Scanner

DSS Coverage

Coverage verification allows identification of service gaps or death-zones where pilot signals are below acceptable sensitivity levels of user equipment.

Coverage gaps will cause call drops or fallbacks, impacting throughput of mobile users.

DSS coverage is validated by the power level of the specific reference signals of 4G-LTE and 5G-NR



OneAdvisor DSS Signal Analysis – RouteMap

Ordering Information

Part Number	Description
ONA800A-SPO-A	OneAdvisor-800A Spectrum Analyzer 9KHz to 6GHz with Optical Hardware (CPRI) – Bluetooth, Wi-Fi, Smart Access Anywhere – GPS connectivity w/GPS antenna – Realtime Spectrum Analysis 100MHz – Interference Analysis and Gates Sweep Spectrum – Spectrum Route Map – Mag mount RF omni antenna SMA_f 600 MHz to 6 GHz – GPS SMA mount antenna – External battery charger, additional battery, and cigarette lighter adapter
ONA-SP-LTEFDDOTA	LTE-FDD OTA Signal Analysis
ONA-SP-LTETDDOTA	LTE-TDD OTA Signal Analysis
ONA-SP-5GOTA	5GNR OTA Beamforming analyzer
ONA-SP-DSSOTA	OneAdvisor OTA DSS Analysis Option

References

- 3GPP 36.300 Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2
- 3GPP 36.211 Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation
- 3GPP 38.104 Technical Specification Group Radio Access Network; NR; Base Station (BS) radio transmission and reception
- 3GPP 26.261 Technical Specification Group Services and System Aspects; Service requirements for the 5G system; Stage 1
- 5G White Paper 2; ngmn.org

For more information, visit our OneAdvisor-800 page.

VIAVI Solutions

Contact Us **+1 844 GO VIAVI**
(+1 844 468 4284)

To reach the VIAVI office nearest you, visit viavisolutions.com/contact

4g5g-signalanalysis-an-xpf-nse-ae
30192976 900 0221