VIAVI Solutions

Application Note

VIAVI
OneAdvisor 800
EMF Signal Analysis

VIAVI OneAdvisor 800 Wireless is the ideal field test solution for radio access networks, performing comprehensive tests for the effective maintenance and optimization of cell sites.

The radios deployed in cell sites must comply with the electro-magnetic field (EMF) emissions according to thresholds defined by government agencies and regulators responsible for public health and safety.

There are two main test methodologies to measure EMF in cell sites:

- Spectrum-based: (frequency selective) measures all power in the band where the signal of interest is transmitting.
- Beam-based: (code selective) measures the power of 5G NR beams and performs a power extrapolation to assess the total emission of 5G NR radios.

OneAdvisor 800 EMF Analysis
(Spectrum and Beam)

Benefits of OneAdvisor 800 Wireless EMF Spectrum Analyzer

- Frequency selective spectrum analysis and integrated scanner measurement mode
- Multi-trace analysis with average, maximum and minimum EMF power logging
- Configurable test time up to 60 minutes
- Automatic control of an isotropic antenna

Benefits of OneAdvisor 800 Wireless EMF 5G NR Analyzer

- Code selective extrapolated 5G EMF power assessment and power variation analysis
- Supports all 3GPP 5G NR channel configurations: NSA and SA modes, in FR1 or FR2 band
- Automatic SSB search and PCI detection
- EMF power measurements per radio (PCI) including SSB beams and traffic beams

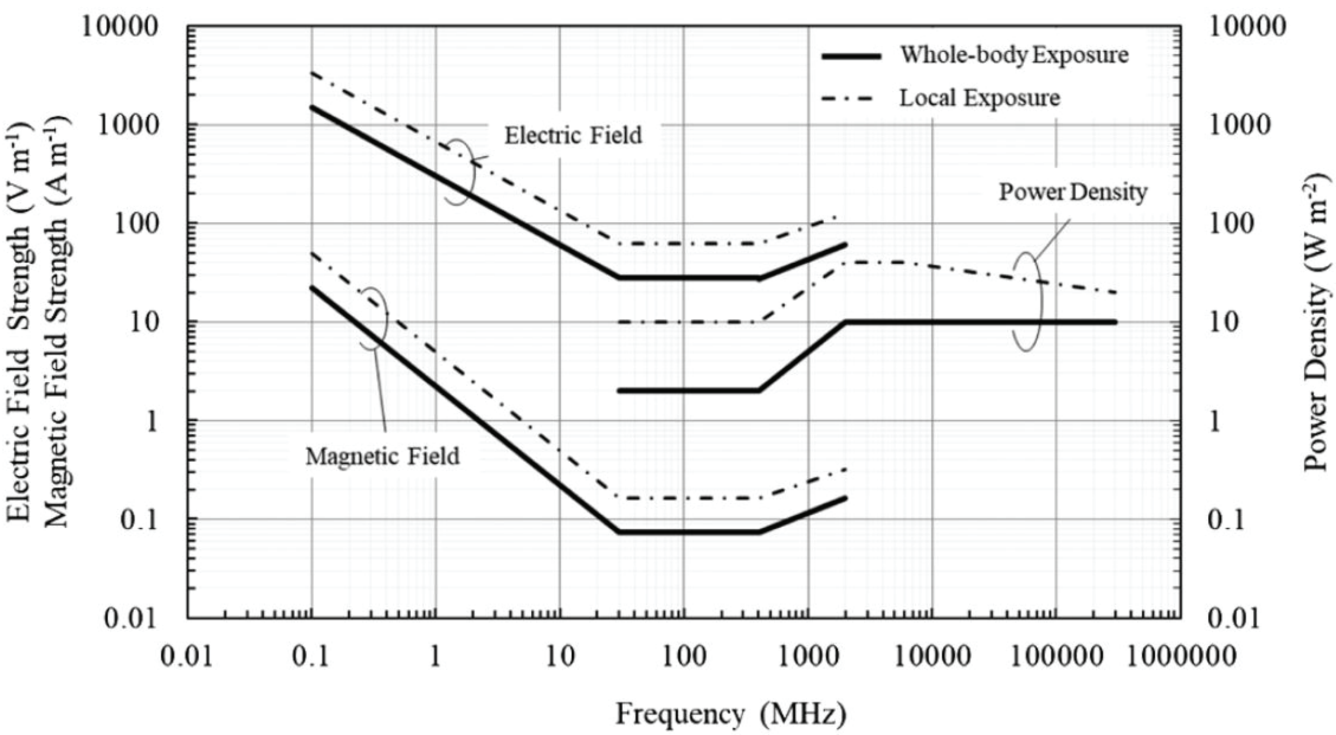
OneAdvisor 800 Wireless
All-in-one test solution for the best total cost of ownership

Radios in cell sites transmit electric and magnetic waves over the air, in the case of 5G NR radios the frequency of those waves are currently classified in two different frequency ranges:

- Frequency range 1 (FR1): 410 MHz to 7,125 MHz
- Frequency range 2 (FR2): 24,250 MHz to 71,000 MHz

The radiation levels in those frequency ranges do not cause any molecular change (ionization), therefore it is referred as non-ionizing radiation, and is typically measured as the energy of the electromagnetic field (EMF) in a certain area or volts per meter (V/m); also, it can be represented as power density or power flow per unit area in terms of watts per square meter (W/m2). Other scale units like dBuV/m, dBmV/m, dBV/m, dBm/m2, A/m, mW/cm2, dBA/m or % are supported.

Several organizations including the Institute of Electrical and Electronics Engineers (IEEE), and the International Commission on Non-Ionizing Radiation Protection (ICNIRP), have issued recommendations for human exposure to RF electromagnetic fields, which protect from effects associated with heating.



ICNIRP Levels for general public exposures (average time of ≥6 min, from 100 kHz to 300 GHz)

VIAVI OneAdvisor 800 Wireless supports measurement references based on ICNIRP Occupational and General Public limits, including also other standards like ARPANSA, BGV, FCC, IEEE, Italy CM and Safety Code 6.

This solution also allows a user to customize any other standard limits required and save them for continued use.

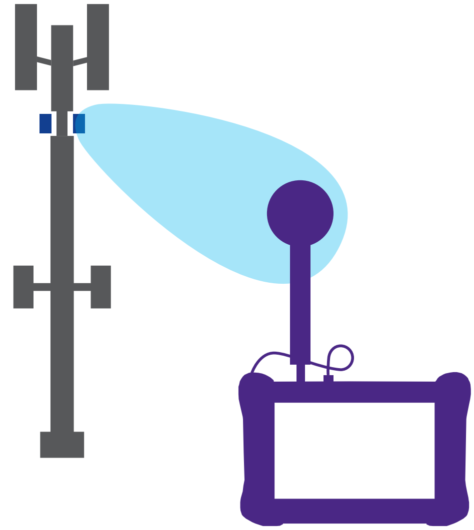
*3GPP Rel. 18, TS 38.101

EMF Spectrum Analysis

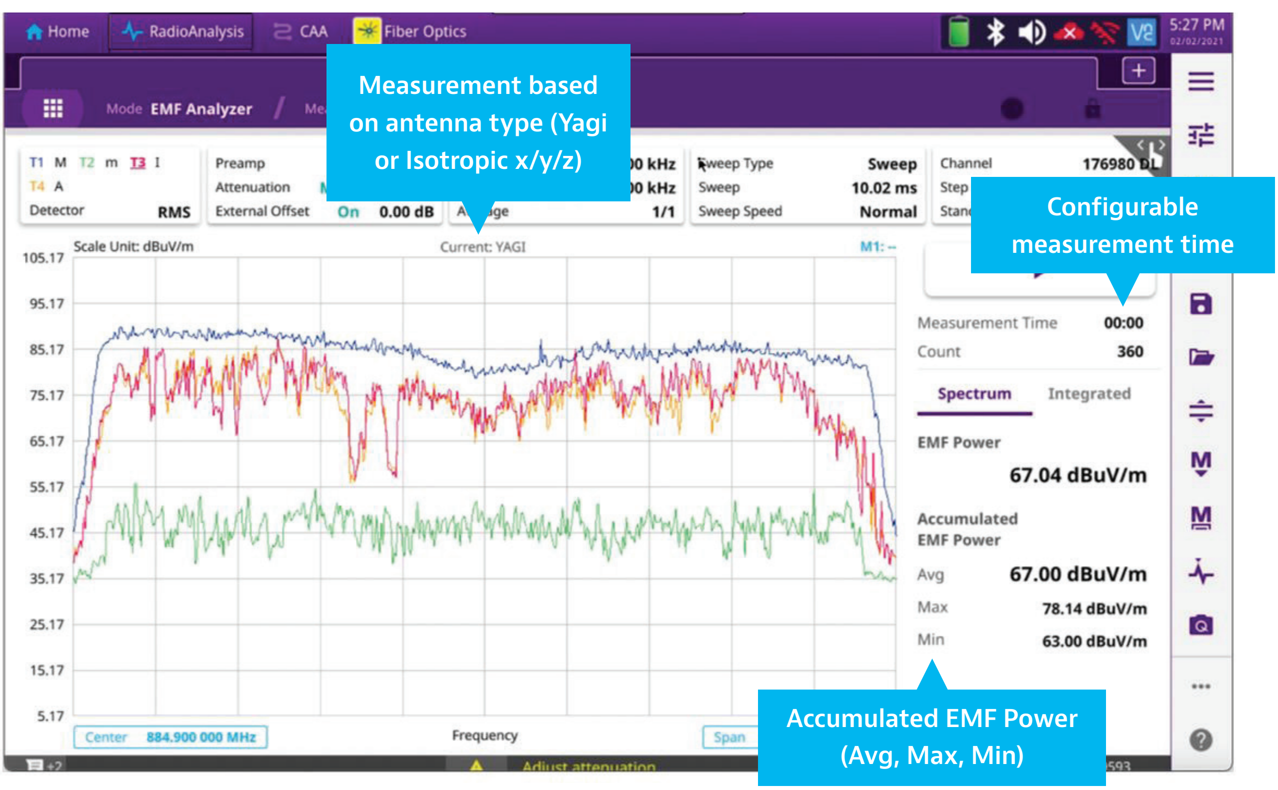
OneAdvisor 800 Wireless with EMF Spectrum Analysis function measures, in frequency selective mode, all radiation power in a defined frequency band, integrating all the power received in a configurable test time, from 1 to 60 minutes currently.

The EMF Spectrum Analysis method is applicable for most RF signals in the field, particularly for cellular signals with a frequency division duplex (FDD) configuration.

EMF Spectrum Analysis tests can be conducted with an isotropic antenna, performing a 3-axis power measurement controlled by the OneAdvisor 800 test set, but also with other types of antennas.



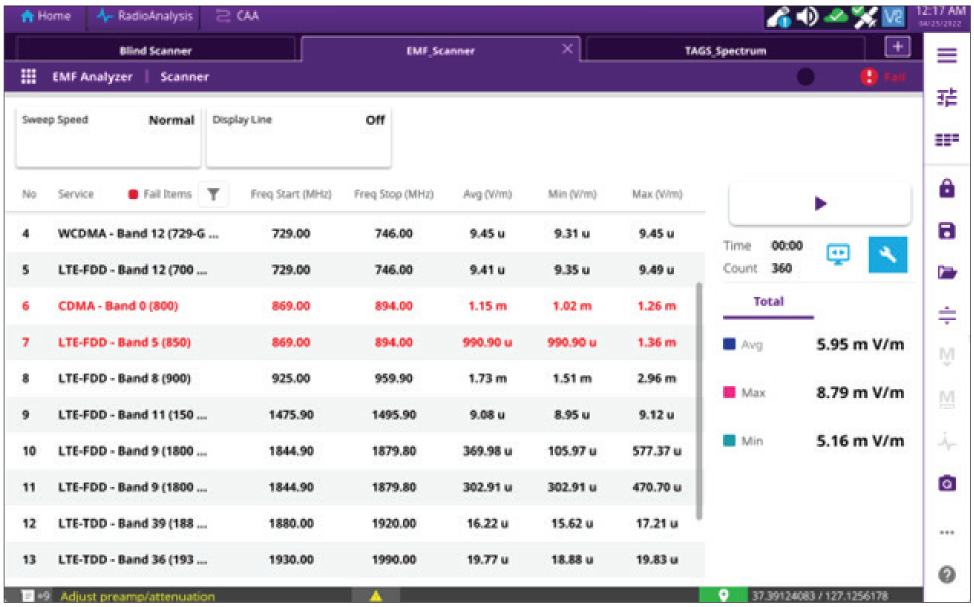
OneAdvisor 800 Wireless EMF Spectrum Analysis



OneAdvisor 800 Wireless EMF Spectrum Analysis (frequency selective mode)

In addition, as part of the Spectrum Analysis feature set, the instrument can be configured in Scanner mode. This alternative frequency-selective measurement allows to discriminate between different potential sources of radiation per frequency range, e.g. by comparing multiple cellular bands, or even down to single channel bandwidths, and identify those that contribute with higher energy (power density) to the overall EMF emissions.

Thus, the Scanner measurement in frequency selective mode allows for a quick indication of how each separate source of radiation, down to every frequency range of choice, is contributing to the overall existing EMF levels.



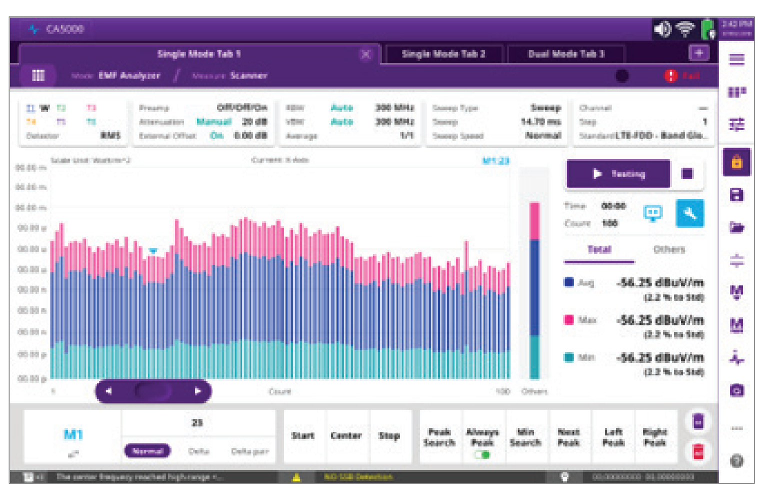
OneAdvisor 800 Wireless EMF Scanner (frequency selective mode)

The Scanner mode can measure multiple spectrum ranges in a sequential fashion and automatically. The results can be presented in a table view format (example above) or in a bar chart view (example below) for effective Avg., Min, and Max EMF powers easy display and quick identification of those frequencies radiating at higher power levels.

The results can also be logged for an extended period of time and saved in a data file for offline post-processing and reporting.

Different lists of frequency ranges can be stored and re-used at any time of choice.

The frequency selective Scanner measurement provides a great advantage over other type of EMF measurement devices like broadband meters, to identify quickly and effectively which transmission systems, radio technologies, frequency bands or even individual channels can be transmitting higher levels or EMF radiation power in any specific location.



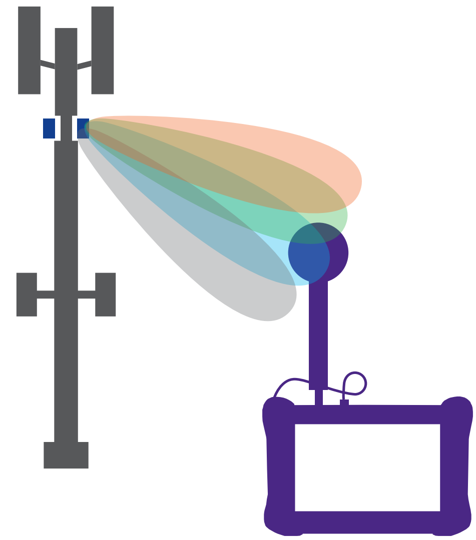
OneAdvisor 800 Wireless EMF Scanner
(frequency selective mode)

EMF 5G-NR Signal Analysis

OneAdvisor 800 Wireless with EMF 5G NR Signal Analysis measures in code selective mode all the radiation power in a defined 5G NR-ARFCN channel, identifying the radio identity number (PCI) and integrating all the power received from 5G NR beams during a configurable test time.

OneAdvisor 800 Wireless EMF 5G-NR Signal Analysis features the unique capability of measuring the radiation power of the reference/coverage beams transmitted through the Synchronization Signal Block (SSB) or alternatively, the radiation power of the traffic beams allocated to a specific data session.

EMF Signal Analysis in code selective mode can be conducted with an isotropic antenna, performing a 3-axis power measurement controlled by the OneAdvisor 800 test set, or a directional antenna.



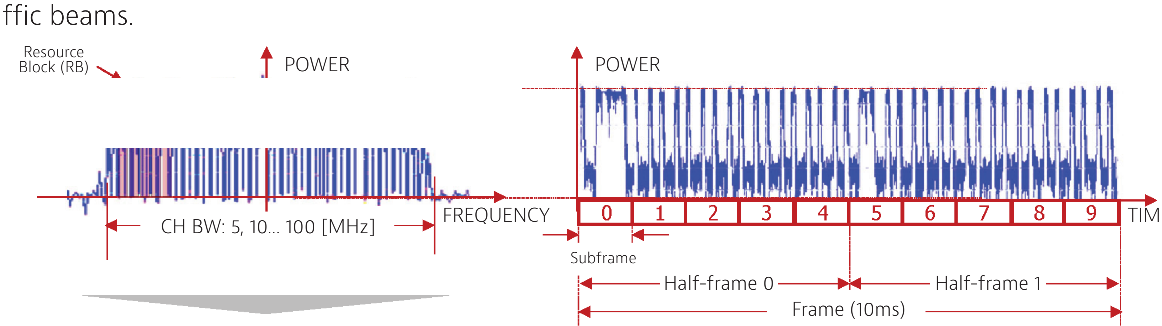
OneAdvisor 800 Wireless EMF 5G NR Signal Analysis

EMF 5G Signal Analysis in code selective mode is the most accurate methodology to test radiation levels from 5G NR radios covering all possible 3GPP 5G NR channel configurations and numerologies, both NSA and SA modes and in FR1 or FR2 bands.

5G Overview

5G New Radio (NR) has been defined to provide an improved set of services and applications, incorporating additional flexibility and functionality than prior LTE, including the following:

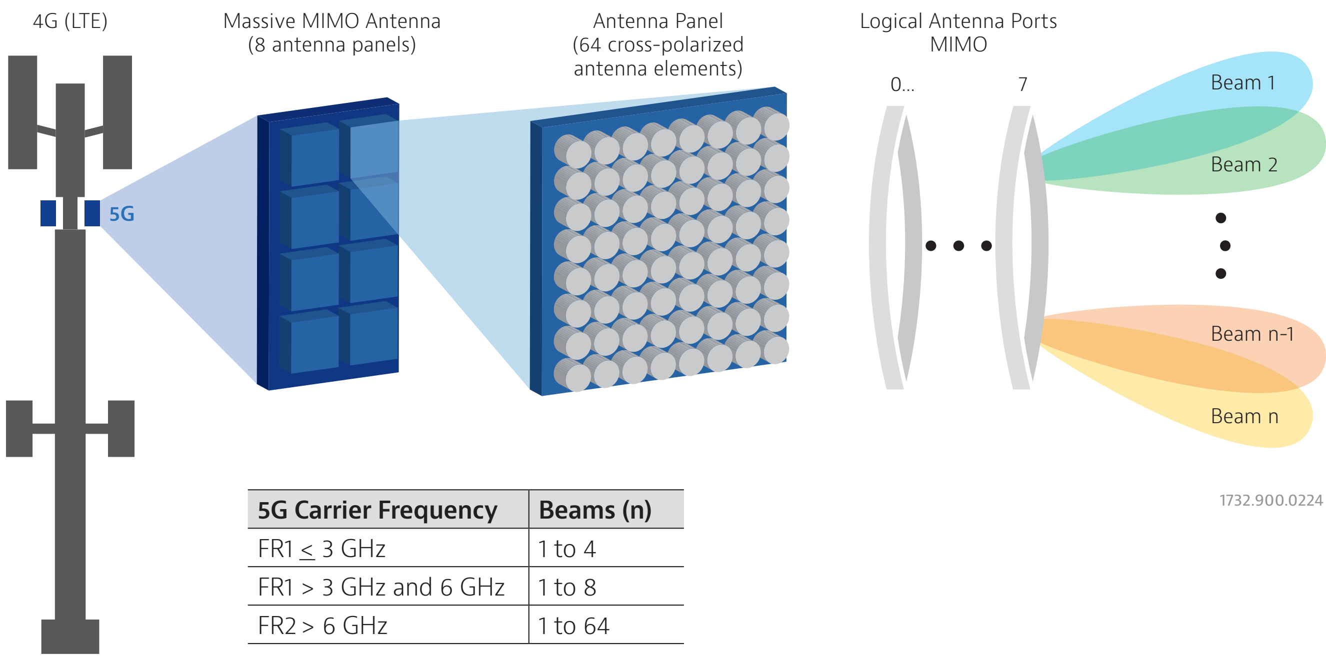
- Channel bandwidth: flexibility for wider channel bandwidth configurations; for example, for frequency range FR1, defined by 3 GPP from 410 MHz to 7,125 MHz the transmission bandwidth can have a range of 5 MHz to 100 MHz and for FR2 the range extends between 24,250 MHz to even 71,000MHz in the latest standard reviews.
- OFDMA structure numerology: the signal frequency components or sub-carriers can be configured at different bandwidths including 15kHz, 30kHz, or 60kHz spacing 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. We can categorize generically two types of beams: those transmitted by the Synchronization Signal Block (SSB) of the channel, also commonly known as coverage or reference control beams, and those transmitting throughout the width of the channel supporting data transmissions over a dynamic allocation of Physical Resource Blocks (PRBs), commonly known as user or traffic beams.



3GPP 5G NR Signal Channel and Frame Structure

5G-NR Beamforming

Beamforming is a distinctive property of 5G NR technology, where multiple narrow beams can be transmitted to the user's equipment (UE), either mobile phones or customer premise equipment, to increase the bandwidth of data transmissions. It is possible by increasing the number of antenna elements in the cell.



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

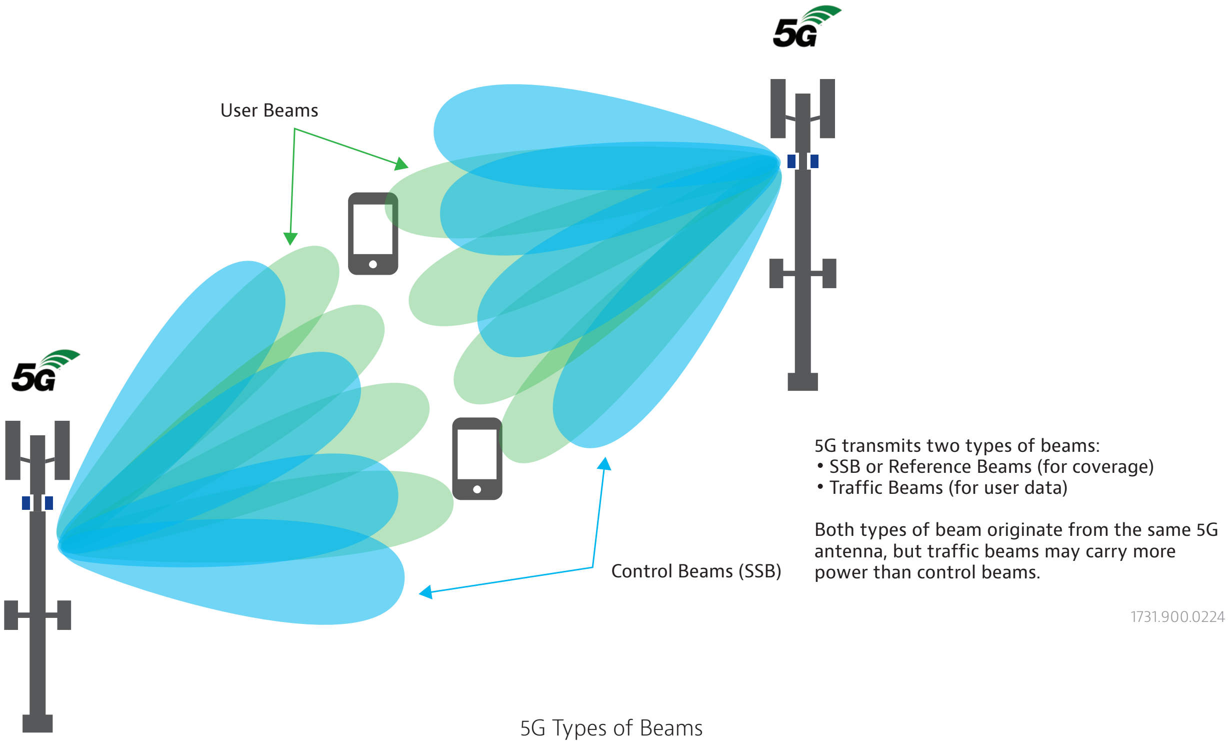
5G Massive MIMO and Beamforming

5G NR cells transmitting at frequencies below 7 GHz 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 3 GHz, and a maximum of 8 for frequencies up to 7 GHz, which is being referred to as the mid-band.

As transmission frequency increases, antenna elements get smaller, therefore 5G NR cells transmitting at frequencies above 24 GHz can be equipped with antenna panels containing several hundreds of elements capable of transmitting up to 64 narrow coverage beams through its Synchronization Signal Block (SSB).

Any 5G user equipment (UE) initiates its cell attachment by performing a cell search of beams in the SSB from which it will acquire synchronization and obtain the physical cell identity (PCI). Once the UE attaches to the radio with that PCI reference it is ready to establish and initiate a dedicated high-speed traffic session.

Here is where a different sort of so-called traffic beams will occur, and to transmit those the radio scheduler will allocate dynamically a number of Physical Resource Blocks (PRB) throughout the bandwidth of the 5G NR channel, to support a high-speed user data transfer.



5G Types of Beams

5G-NR EMF Signal Analysis

The flexibility of TDD signal formats provided by 5G NR standards, i.e., with different numerologies and beamforming options, makes the traditional EMF frequency selective method not the most effective to properly characterize the maximum levels of EMF emissions, because in a 5G channel the power transmission patterns may change significantly over short periods of time, thus driving the need to perform a 5G NR signal analysis test which demodulates the signal and obtains the physical cell identity (PCI), as well as the power levels from all identified beams transmitting from a 5G NR radio sector.

In 5G NR TDD the individual beams are transmitted at different time slots and might have a different power level each. Therefore, it is required to measure the profile of each beam available and then extrapolate this power to obtain the total emitting power of a 5G NR radio through the entire channel bandwidth, considering all of its physical resource blocks.

This alternative methodology is commonly referred to as the code selective method and can apply to either measuring EMF levels from the reference beams transmitting from the “always-on” SSB or alternatively to the traffic beams during a high-speed data transfer session, all serving the end user in a location of choice to perform the measurement.

Accordingly, to evaluate the EMF levels of 5G NR signals more accurately, the code selective method focuses on power levels from the transmitting beams, then making an extrapolation of the results to the entire channel bandwidth.

Extrapolation techniques for 5G NR in code selective mode are discussed in numerous research and academic publications and remain a continued subject of investigation by industry experts, academia and regulatory agencies. [see References]

In general, an extrapolation formula for exposure from 5G NR beams can be defined as below:

$$E_{asmt} = E_{broadcast} \cdot \sqrt{F_{extbeam} \cdot F_{BW} \cdot F_{PR} \cdot F_{TDC}},$$

where:

- E_{asmt} and $E_{broadcast}$ are the extrapolated electric field strength values of the traffic signal in V/m and evaluated (measured) electric field strength of broadcast signal in V/m per given resource element, respectively.
- $F_{extBeam}$ is an extrapolation factor corresponding to the ratio of the equivalent isotropic radiated power (E_{IRP}) envelope of all traffic signals to the E_{IRP} envelope of the broadcast signal in the direction of the POI.
- F_{BW} , F_{PR} and F_{TDC} are the remaining extrapolation factors corresponding respectively to the ratio of the total carrier bandwidth and the subcarrier frequency spacing of the broadcast signal, the power reduction factor and the maximum technology duty-cycle of all the DL traffic beam signals resulting from the configured duplex mode. The power reduction factor is applicable if the actual maximum approach is used and can take a value of several dB.

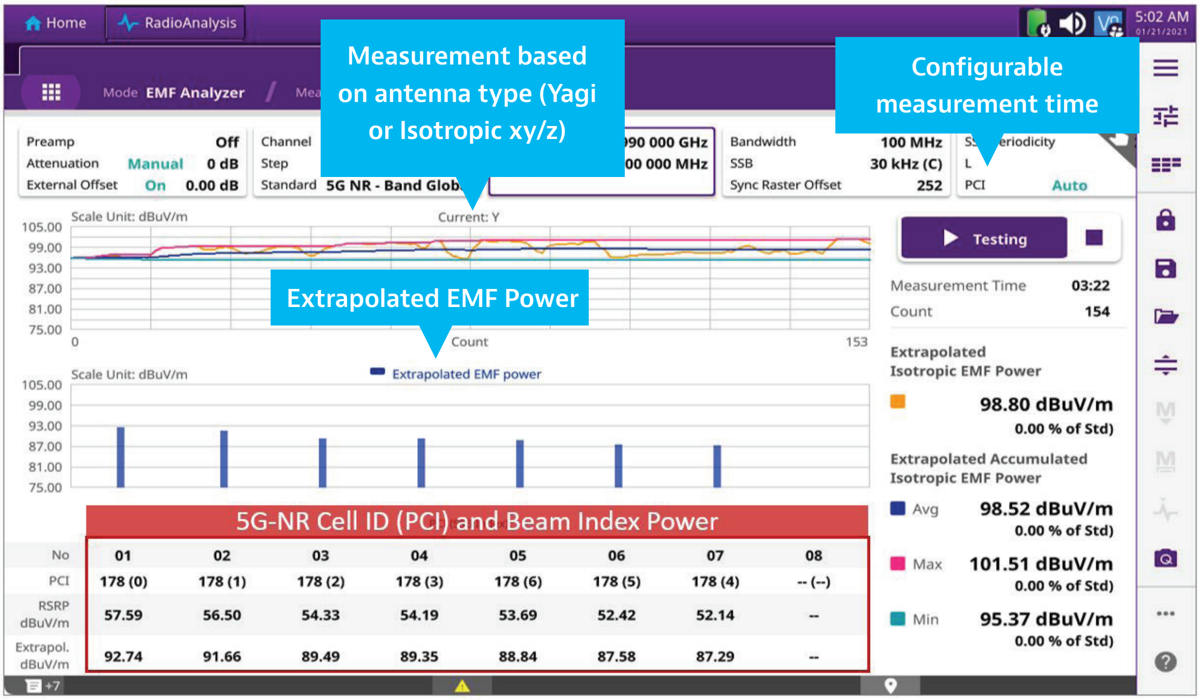
Testing 5G EMF on reference SSB beams

- OneAdvisor 800 Wireless features a comprehensive set of 5G NR signal analysis testing capabilities, with the ability to discriminate every transmitting radio sector (PCI) and the power level and index of each of its corresponding SSB beams.
- Through the code selective method, it can also provide the effective exposure level (EEL) from that 5G NR signal by applying a number of extrapolation factors that considers the overall signal's characteristics, including:
- Transmitting cells (i)
    - ➢ max N=4 (four PCIs)
- Electric field of a beam from a cell ($E_{base,i}$)
- Full carrier transmission factor (R_{FBW})
- Time allocation factor ($R_{Pattern}$)
- Beam system type factor (R_{System})
- Multipath channel factor ($\alpha(\tau,\Delta)$)

Thus, the different factors listed above can be used for an accurate EEL calculation using the extrapolation formula described in the previous section, resulting in the following practical formulation for 5G EMF in code selective mode:

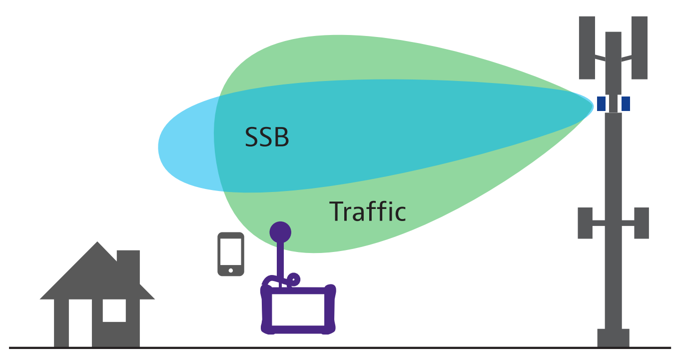
$$\text{EEL (Vm}^{-1}\text{)} = \sum_{i=1}^{N} \sqrt{\alpha(\tau,\Delta) E^2_{base,i} R_{FWB} R_{Pattern} R_{System}}$$

A resulting EMF measurement on SSB beams is shown in the following example, for a 5G NR channel in the mid-band, the PCI and beam index values can be observed, along with the isotropic values and extrapolated EMF power:



Testing 5G EMF on traffic beams

Validating EMF emission levels from 5G NR radios over the reference SSB beams has been for some time the only code selective method available in the market. While this testing procedure was a preferred and more accurate alternative to the traditional frequency selective measurements, there has always been an interest also to measure more specifically EMF emissions from the traffic beams, and especially during a high-speed data session that in many cases it is expected that would theoretically radiate more power into the end users at their individual location.



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5G EMF code selective measurement on traffic beams over a high-speed data transmission

Testing on traffic beam power levels has always presented a significant challenge since the 5G NR radio scheduling system can allocate dynamically a non-fix number of Resource Blocks (PRB) for each stablished user data transfer.

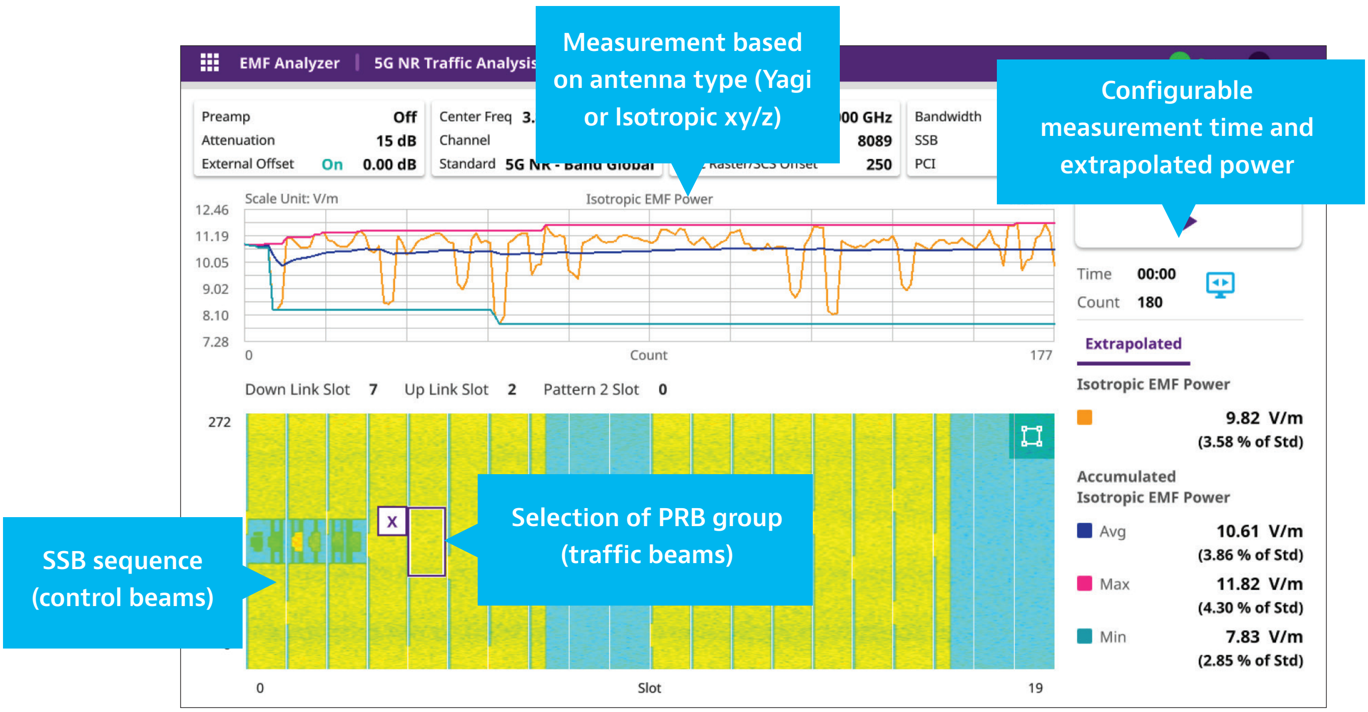
That dynamic allocation of PRB for each data session depends on several factors like the total number of users being served by the radio, the proximity of each UE to the cell site, traffic demand patterns, and similar. Furthermore, there was a lack of measurement solutions in the market with the ability to identify the power levels corresponding to every traffic session specifically, because of the ever-changing allocation of Resource Blocks throughout the 5G NR channel.

To address this challenge, VIAVI Solutions has introduced a very innovative, patent-pending measurement based on our 5G Data Allocation Mapper, which provides a quick and effective view for the allocation of all the power levels per Resource Block in a 5G NR Frame. This can be graphically displayed through the number of slots available in a 10msec frame (note the total number of slots per frame will depend on the 5G signal numerology being used).

For 5G EMF on traffic beams, based on the group of PRBs allocated, the extrapolation formula is modified as shown:

$$\text{EEL (Vm}^{-1}\text{)} = \sqrt{E^2_{\text{base, area, average power}} R_{\text{FBW}} R_{\text{Pattern}}}$$

where E_(base,area average power) is the electric field strength for the group of PRB's average power in the 10msec frame, and R_FBW and R_pattern are the same adjustment factors.



OneAdvisor 800 Wireless 5G EMF Traffic Analysis (code selective mode)

Summary

The key objective for protection against ionizing and non-ionizing radiation is to prevent damage to people and the environment, including fauna and flora ecosystems. National authorities and telecom agencies typically follow recommendations from the International Commission for Non-Ionizing Radiation Protection (ICNIRP), defining guidelines on limiting exposure to radiofrequency EMF to protect the public.

Cellular radio communication sites, including the latest 5G NR ones, emit radiofrequency electromagnetic fields (RF EMF) in a range from several hundred's MHz to several tens' GHz. 3GPP 5G NR technology not only needs to be fast and with higher data throughputs, but most importantly also safe – especially from a public health and safety standpoint.

EMF measurements are necessary to demonstrate that electromagnetic radiation does not exceed the regulated limits. Assessments of personal exposure levels to radiation are most accurately achieved through onsite field measurements. There are two main testing procedures in the market to assess the EMF radiation of 3GPP cellular radiofrequency signals.

The Frequency selective method has been a traditional methodology, commonly used to verify radiation levels of any type of radio technologies, including non-cellular ones. This methodology remains valid also, especially for FDD signals in the cellular industry. With the use of an isotropic antenna, this method in spectrum mode allows for a very complete analysis of the radiation levels of any frequency range – and in scanner mode it allows for a detailed comparison of the radiation levels produced by multiple frequency ranges, down to a single cellular band or individual channel.

The Code selective method addresses the shortcomings of the frequency-based methodology for certain types of signals like TDD ones and is particularly suitable for 5G NR channels that operate in high-frequency ranges with beamforming through the SSB transmission. This method requires demodulation of the 5G channel reference signals and makes use of a signal synchronization mode, based on the individual transmission of a single radio identified by its PCI reference number. While this methodology has been typically applied to verify EMF emissions from SSB beams, also known as control, reference or coverage beams, VIAVI has introduced a new variant of this method. It allows to verify the power emission levels of the traffic or user beams, which may increase the level of radiation onto the user during a high-speed data transfer from the radio base-station down to the user equipment, i.e., a phone or any other type of user equipment.

References

CEPT – Electronic Communications Committee – WG Frequency Management – FM 22 Monitoring and Management – FM22(23)07 EMF measurement of 5G base stations using AAS

IEEE C95-1; Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz

International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines for limiting exposure to electromagnetic fields (100 kHz to 300 GHz)

3 GPP TS 38.104; 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; NR; Base Station (BS) radio transmission and reception (Release 16)

Kamil Bechta; Christophe Grangeat; Jinfeng Du; Marcin Rybakowsk, "Analysis of 5G Base Station RF EMF Exposure Evaluation Methods in Scattering Environments", IEEE Access, vol. 10, pp. 7196-7206, 2022.

IEC 62232:2022 (Annex B.8, E.7, E.8)

For more information, visit our OneAdvisor 800 Wireless page.

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