Selective Radiation Meter SRM-3006

Application Note

narda Safety Test Solutions

Immission measurements in the vicinity of LTE base stations

Part 1: Principles

This Application Note looks at the practical performance of immission measurements in the vicinity of LTE base stations using the Selective Radiation Meter SRM-3006. General information on performing immission measurements in the vicinity of fixed transmitters can be found in the Application Note [WUS 12] from Narda Safety Test Solutions and is only briefly mentioned here. This document focuses on the SRM-3006 processes specifically designed for LTE measurements, along with the settings that need to be made on the SRM-3006 and the evaluation of the measurement results.

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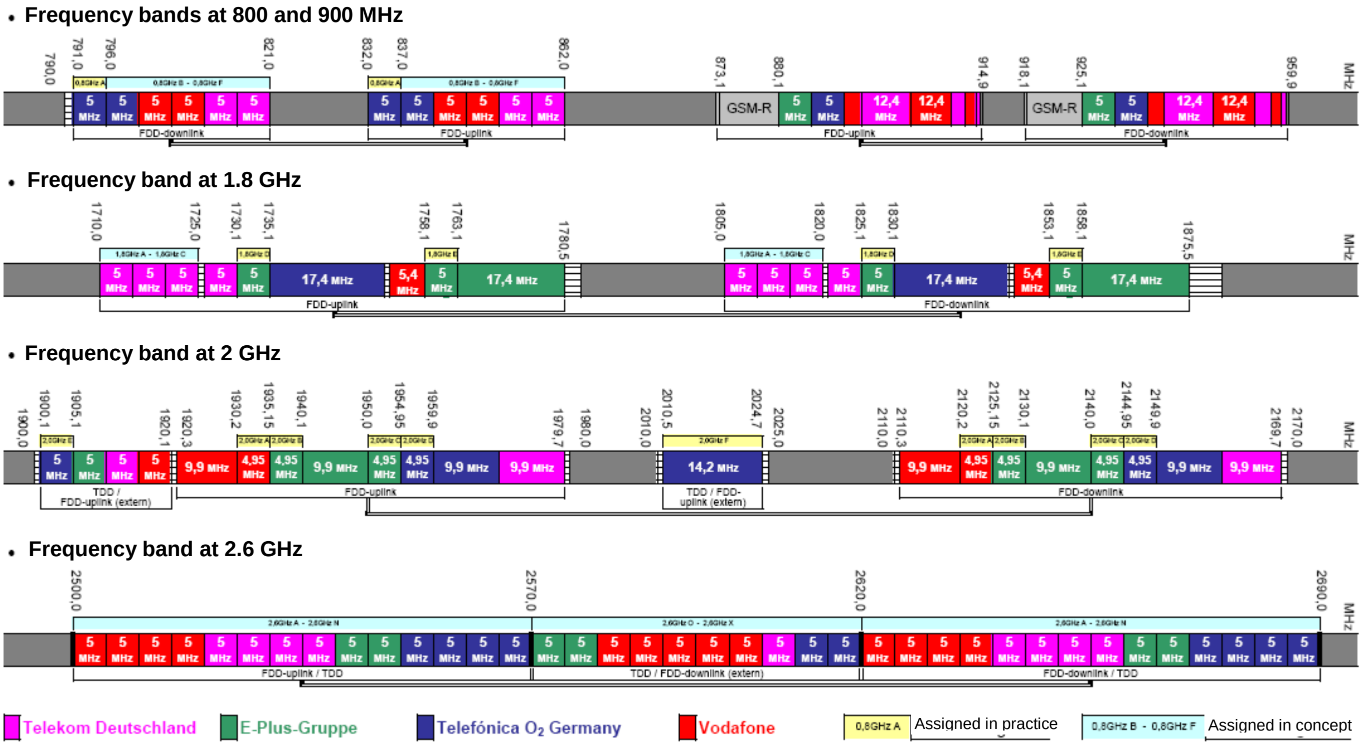
The new LTE mobile technology

LTE (Long Term Evolution) is the designation for a new mobile technology that is currently being rolled out in many countries around the globe. Compared with its precursors GSM and UMTS, LTE is characterized by higher data rates, more efficient utilization of the frequency spectrum, and lower latency times.

LTE can be operated in principle within various frequency bands from around 700 MHz up to 2700 MHz. The frequencies are usually auctioned off by the relevant regulating authority. As an example, the auction in Germany in 2010 covered frequencies in the 800 MHz, 1.8 GHz, 2 GHz and 2.6 GHz bands (Figure 1). The German mobile telecommunications providers are currently establishing LTE networks in the 800 MHz (LTE-800, "Digital Dividend") and 1800 MHz (LTE-1800) frequency bands. LTE channel bandwidths are specified at 1.4 MHz, 3 MHz, 5 MHz, 10 MHz and 20 MHz; the networks currently operating in Germany mainly use 10 MHz (LTE-800) and 20 MHz (LTE-1800).

Figure 1: LTE frequencies in Germany. Frequency spectra in the 800 MHz, 900 MHz, 1.8 GHz, 2 GHz and 2.6 GHz bands with "Assigned frequencies for wireless network access for providing telecommunications services" (yellow and light blue fields) [BNETZA 10].



The networks are often operated in FDD mode (frequency division duplex), i.e. the uplink and downlink use different carrier frequencies.

The typical transmitting power of an LTE base station is around 20 to 50 W per channel, which makes it comparable to the channel output power of the established GSM and UMTS stations. It should, however, be noted that the signal transmitted by LTE base stations is usually radiated through two channels simultaneously by excitation of the +45° and -45° polarization layers of a cross-polarized base station antenna, also known as MIMO (multiple input multiple output). This has implications for the immission measurement, which will be explained below.

Fundamental measurement method

LTE base stations are fixed location radio transmitters used for commercial purposes and which operate at power levels of 10 W EIRP (equivalent isotropic radiation power) or more. This means that they are subject to immission protection regulations such as the "Twenty-sixth Regulation for Implementing the Federal Immission Protection Law (Regulation on Electromagnetic Fields)" [26. BImSchV] that applies in Germany.

This Regulation along with the explanatory instructions on how to implement it issued by the Federal State Committee for Immission Protection [LAI 04] specify that immission protection measurements must be carried out "*at the location where the exposure levels are strongest*", and an assessment of the measurement results should be made "*on the basis of the maximum values measured*". Additionally, *"the measurements should be made at the maximum operational load of the system or correspondingly extrapolated where this is not possible*".

These regulations stipulate that the instantaneous immission at any location cannot be used for a measurement complying with the legal requirements; instead, the maximum immission must be measured at the *location* and *time* of occurrence.

Determining the *location* of the maximum can be done using the pendulum method, for example: The space to be measured is sampled using a hand-held measuring antenna. If the antenna is directional, the main axis and polarization direction of the measuring antenna should also be varied during the pendulum procedure. The immission is recorded continuously during the pendulum process using the *Max Hold* function of the measuring instrument. The result is the maximum immission value occurring within the space that was sampled. Locating the local maximum is necessary because the immission can vary greatly within a small area due to interferences, especially indoors [BOR 06].

The pendulum method has become established as a standard method of determining the maximum immission within a specific space. The LAI in Germany recommends its use [LAI 04], and at the European level it is explicitly mentioned as an alternative measurement method in the EN 50492 standard: "*Basic Standard for the In-Situ Measurement of Electromagnetic Field Strength related to Human Exposure in the Vicinity of Base Stations*" [EN 50492]. The EN 50492 standard also provides for a measurement using a grid of three or six spatially distributed measurement points for measurements where the immission *averaged over the volume of the human body* is the assessment quantity. As already described in [WUS 12], the method to be used for recording the local measurement values essentially must be decided according to the relevant regulations or the measurement task assigned. In no way to be recommended is the still widespread practice of setting a probe on a tripod to measure the immission at a fixed point in the space, because a single spatial point is not representative of the maximum or the average immission in the space under investigation.

Figure 2: LTE measurement with the SRM-3006 and an isotropic antenna.

Measurement of the *time* at which the maximum occurs is usually based on measuring the immission of certain signals that are radiated from the base station at a constant, defined output power that is *independent* of the traffic load. Using the ratio of the maximum possible output power of the base station (i.e. that requested from the regulatory authority) to the power of the measured signaling channel, a reliable extrapolation can be made to determine the immission at the maximum operating load of the system. This Application Note looks in detail at the signaling that is suitable for such measurements on LTE stations, and how the measurement is performed in practice.

Both three axis (isotropic) and single axis (e.g. log-periodic) antennas are basically suitable as measuring antennas. For LTE measurements, Narda offers several three axis and single axis antennas for electric fields (see Table 1). Use of these antennas has the advantage that the antenna factors are stored in an EEPROM in each case and are automatically uploaded and applied when the antenna is connected to the basic unit.

Designation	Number of axes	Frequency range	Measurement dynamic range (typical) when used with SRM-3006
3501/03	Three (isotropic)	27 MHz – 3 GHz	0.2 mV/m – 200 V/m
3502/01	Three (isotropic)	420 MHz – 6 GHz	0.14 mV/m – 160 V/m
3531/01	One	27 MHz – 3 GHz	60 µV/m – 80 V/m

Table 1: Overview of Narda measuring antennas for LTE measurements with the SRM-3006.
See data sheet from Narda for definition of measurement dynamic range.

Structure of LTE base station signals

It is a good idea to get acquainted with the fundamental structure of LTE base station signals in order to better understand the different measurement methods described in Part 2 of this Application Note. The following focuses on such LTE signals as are used with the base stations currently available in Germany (i.e. FDD signals with normal cyclic prefix CP).

The smallest time unit of an LTE signal has a duration of about 71 µs and is called a “symbol”. Seven consecutive symbols form a “slot” (0.5 ms), and 20 consecutive slots form an “LTE frame” (10 ms). In the frequency domain, the LTE signal comprises many sub carriers with a carrier spacing of 15 kHz because of the modulation method OFDMA (orthogonal frequency division multiple access) that is used. The smallest time-frequency unit, i.e. one sub carrier in one symbol (15 kHz x 71 µs) is called a resource element (RE).

Multipath propagation causes the symbols to reach the receiver with different delays. To avoid intersymbol interference (where different symbols overlap in time), a prefix is added to each symbol by the transmitting side, which is removed again by the receiver.
The normal prefix is sufficient for smaller cells; the extended prefix is used by network operators for cells that cover a wide area.

12 consecutive sub carriers and 7 consecutive symbols form a resource block (RB), which comprises 84 REs and covers 180 kHz in the frequency band and 0.5 ms in the time domain.

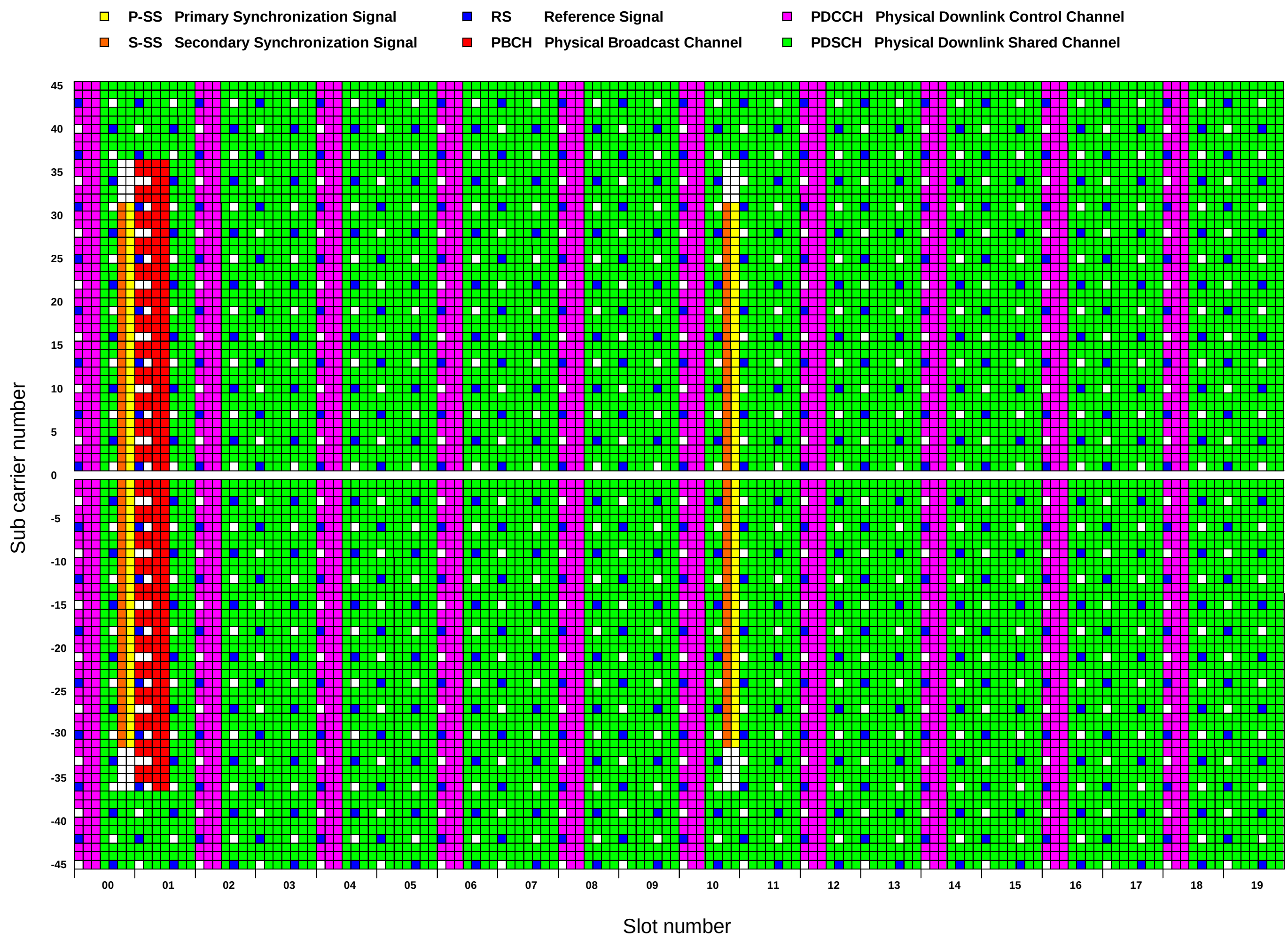


Figure 3: Resource grid of the LTE base station signal in one antenna layer of 2 antenna MIMO, according to [BOO]

Figure 3 shows the structure of the LTE signal described above. The X axis represents time (1 frame, i.e. 20 slots) and the Y axis represents frequency (in this case the sub carriers from -45 to +45 relative to the center frequency of the signal). Each separate small box represents a RE. This type of diagram is known as a “resource grid”. The REs are occupied by various signals and channels; their locations in the resource grid can be seen in Figure 3. Refer to [BOR 13], for example, for the descriptions and functions of the physical channels and signals.

Regularly reoccurring structures can be seen in the resource grid, such as those of the P-SS and S-SS synchronization signals (twice per frame, i.e. every 5 ms), the PBCH (once per frame, i.e. every 10 ms), or also of the PDCCH (ten times per frame, i.e. every millisecond). In particular, the REs shaded blue in the diagram, which are distributed regularly over the entire signal, are of importance for the code selective measurement described in Part 2 of this Application Note. These represent the reference signal, which is used among other things to estimate the quality of the wireless channel. The REs shaded green are used to transport user data. These REs are usually empty (the affected carriers are disabled) as long as the LTE base station is not handling any traffic, i.e. is only radiating signaling information. This leads to the traffic load affecting the structure of the base station signal. The signal is mainly dominated by the periodically recurring signaling when there is little or no traffic load, but the gaps between the signaling are filled with traffic as the traffic load increases until the signal becomes an unbroken line when the maximum traffic load is reached (for the sake of simplicity, it is assumed that all REs are radiated at the same power level). The two extremes (no traffic / maximum traffic) are shown in Figure 4.

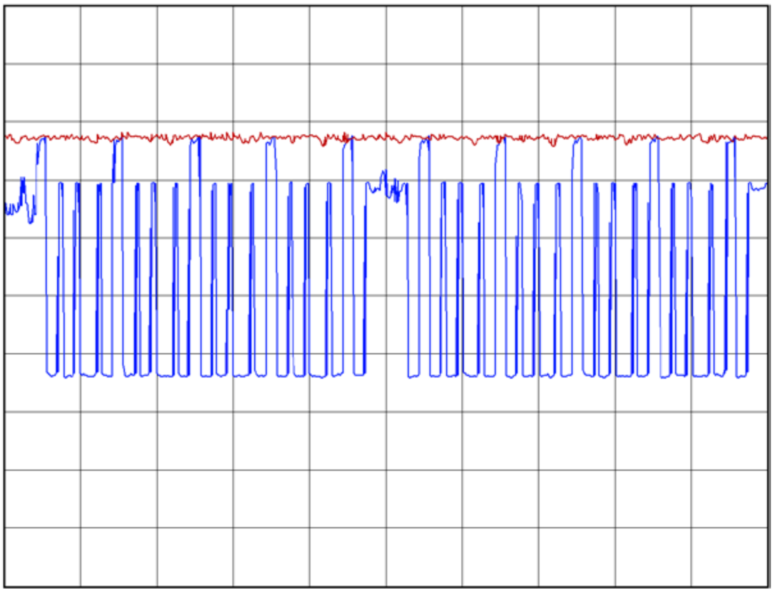


Figure 4: LTE FDD signal in the time domain without traffic (blue) and with maximum traffic (red) (from [BOR 13])

Settings:
Center frequency 806 MHz
RBW 10 MHz, VBW 10 MHz
X scale 1 ms/div.
Y scale 10 dB/div.

Part 2 of this Application Note discusses
– Code selective measurement and
– Spectral measurement
with practical examples.

Document name:
AN_HF_1064_E_LTE_Measurement_methods

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Abbreviations

GSM	Global System for Mobile Communications, 2nd generation mobile communications standard
UMTS	Universal Mobile Telecommunications System, 3rd generation mobile communications standard
LTE	Long Term Evolution, 4th generation mobile communications standard
CP	Cyclic prefix
FDD	Frequency division duplex
MIMO	Multiple input multiple output
OFDMA	Orthogonal frequency division multiple access, modulation method for LTE
PBCH	Physical broadcast channel
PDCCH	Physical downlink control channel
P-SS	Primary synchronization signal
RB	Resource block
RE	Resource element
RS	Reference signal
S-SS	Secondary synchronization signal
TDD	Time domain duplex

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