Outline

- **Motivation for LTE**
- **LTE technology basics**
  - Key parameters
  - OFDMA and downlink frame structure
  - SC-FDMA and uplink frame structure
  - Network and protocol architecture
  - LTE UE categories
- **Radio procedures**
  - Cell search
  - System information broadcast
  - Random access
  - EPS bearer setup
  - Downlink and uplink data transmission
  - Mobility
  - MIMO
- **LTE test requirements**
  - eNodeB RF testing
  - UE RF testing
  - LTE wireless device testing from R&D up to conformance
  - LTE field trial testing and coverage measurements

MIMO = Multiple Input Multiple Output
EPS = Evolved Packet System
UE = User Equipment
RRM = Radio Resource Management
OFDMA = Orthogonal Frequency Division Multiple Access
SC-FDMA = Single Carrier Frequency Division Multiple Access

LTE test requirements

eNodeB RF testing







LTE RF Testing Aspects

Base station (eNodeB) according to 3GPP

- **Measurements are performed using Fixed Reference Channels (FRC) and EUTRA Test Models (E-TM),**
- **Tx characteristic (= Downlink)**
  - Base station output power
  - Output power dynamics,
    - RE Power Control dynamic range, total power dynamic range,
  - **Transmit ON/OFF power,**
    - Transmitter OFF power, transmitter transient period,
  - **Transmitted signal quality**
    - Frequency Error, Error Vector Magnitude (EVM), Time alignment between transmitter antennas, DL RS power, etc. ...
  - **Unwanted emissions,**
    - Occupied Bandwidth, Adjacent Channel Leakage Power Ratio (ACLR), Operating band unwanted emissions, etc. ...
  - **Transmitter spurious emissions and intermodulation,**
- **Rx characteristics (= Uplink)**
  - Reference sensitivity level, Dynamic range, In-channel selectivity, Adjacent channel selectivity (ACS) and narrow-band blocking, Blocking, Receiver spurious emissions, Receiver intermodulation
- **Performance requirements,**
  - ...for PUSCH,
    - Fading conditions, UL timing adjustment, high-speed train, HARQ-ACK multiplexed in PUSCH,
  - ...for PUCCH,
    - DTX to ACK performance, ACK missed detectior PUCCH format 1a (single user), CQI missed detection for PUCCH format 2, ACK missed detection PUCCH format 1a (multiple user)
  - PRACH performance,
    - FALSE detection probability, detection requirements,

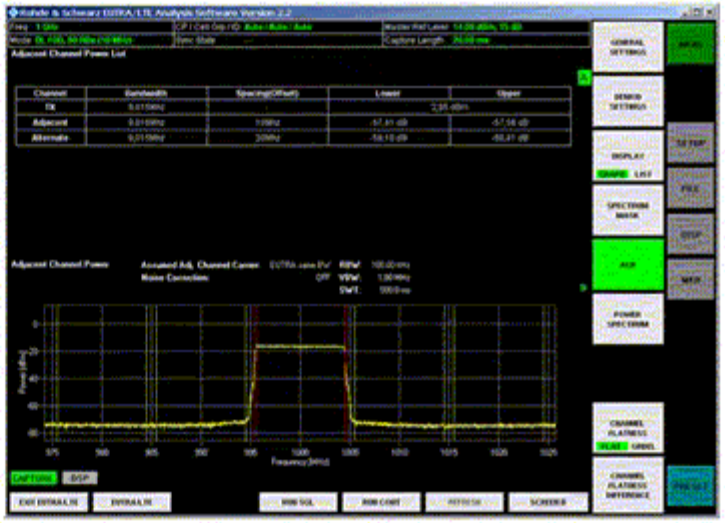
Captured in TS 36.104: Base Station (BS) radio transmission and reception

eNB modulation quality measurements

- Frequency error,
  - If frequency error is larger than a few subcarrier, demodulation at the UE might not work properly and cause network interference,
  - Quick test: OBW, Limit for frequency error after demodulation 0.05 ppm + 12 Hz (1ms),
- Error Vector Magnitude (EVM),
  - Amount of distortion effecting the receiver to demodulate the signal properly,
  - Limit changes for modulation schemes QPSK (17.5%), 16QAM (12.5%), 64QAM (8%),
- Time alignment,
  - Only TX test defined for multiple antennas, measurement is to measure the time delay between the signals for the two transmitting antennas, delay shall not exceed 65 ns,
- DL RS power
  - "Comparable" to WCDMA measurement CPICH RSCP; absolute DL RS power is indicated on SIB Type 2, measured DL RS power shall be in the range of ±2.1 dB,

ACLR in DL (FDD)

No filter definition in LTE!



E-UTRA transmitted signal channel bandwidth $BW_{Channel}$ [MHz]	BS adjacent channel centre frequency offset below the first or above the last carrier centre frequency transmitted	Assumed adjacent channel carrier (informative)	Filter on the adjacent channel frequency and corresponding filter bandwidth	ACLR limit
1.4, 3.0, 5, 10, 15, 20	$BW_{Channel}$	E-UTRA of same BW	Square (BW_{Config})	44.2 dB
	$2 \times BW_{Channel}$	E-UTRA of same BW	Square (BW_{Config})	44.2 dB
	$BW_{Channel}/2 + 2.5$ MHz	3.84 Mcps UTRA	RRC (3.84 Mcps)	44.2 dB
	$BW_{Channel}/2 + 7.5$ MHz	3.84 Mcps UTRA	RRC (3.84 Mcps)	44.2 dB

NOTE 1: $BW_{Channel}$ and BW_{Config} are the channel bandwidth and transmission bandwidth configuration of the E-UTRA transmitted signal on the assigned channel frequency.

NOTE 2: The RRC filter shall be equivalent to the transmit pulse shape filter defined in [15], with a chip rate as defined in this table.

eNB performance requirements

PRACH and preamble testing I

- **PRACH testing is one of the performance requirements defined in 3GPP TS 36.141 E-UTRA BS conformance testing,**
  - Total probability of FALSE detection of preamble (Pfa 0.1% or less),
  - Probability of detection of preamble (Pd = 99% at defined SNR),
  - Two modes of testing: normal and high-speed mode,
    - Different SNR and fading profiles are used (table shows settings for normal mode),

Number of RX antennas	Propagation conditions (Annex B)	Frequency offset	SNR [dB]				
			Burst format 0	Burst format 1	Burst format 2	Burst format 3	Burst format 4
2	AWGN	0	-14.2	-14.2	-16.4	-16.5	-7.2
	ETU 70	270 Hz	-8.0	-7.8	-10.0	-10.1	-0.1
4	AWGN	0	-16.9	-16.7	-19.0	-18.8	-9.8
	ETU 70	270 Hz	-12.1	-11.7	-14.1	-13.9	-5.1

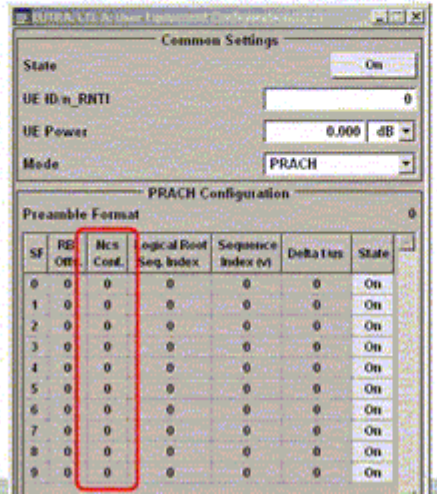
- Depending on the mode different preambles are used to check detection probability (table shows preamble to be used for normal mode),

Burst format	N_{cs}	Logical sequence index	v
0	13	22	32
1	167	22	2
2	167	22	0
3	0	22	0
4	10	0	0

eNB performance requirements

PRACH and preamble testing II

- **According to 3GPP TS 36.211 the N_{CS} value is not set directly instead it is translated to a N_{CS} configuration value,**
  - This value is set in the signal generator R&S® SMx or R&S® AMU,



Screenshot taken from R&S® SMU200A Vector Signal Generator

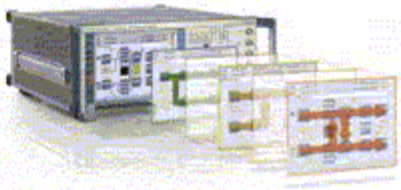
N_{CS} Configuration	N_{CS} value	
	Unrestricted set	Restricted set
0	0	15
1	13	18
2	15	22
3	18	26
4	22	32
5	26	38
6	32	46
7	38	55
8	46	68
9	59	82
10	76	100
11	93	128
12	119	158
13	167	202
14	279	237
15	419	-

R&S®SMx signal generators and
R&S® FSx signal analyzers

R&S®TS8980 LTE RF test system

UE RF testing

R&S®CMW500 wideband radio
communication tester



R&S®SMU200A signal generator and
fading simulator including MIMO

LTE RF Testing Aspects

User Equipment (UE) according to 3GPP

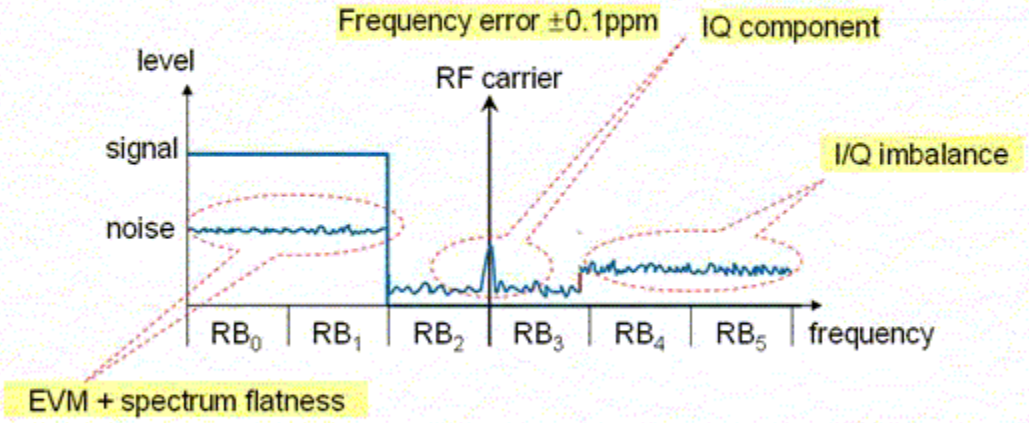
- **Tx characteristic**
  - Transmit power,
  - Output power dynamics,
  - Transmit Signal Quality,
    - Frequency error, EVM vs. subcarrier, EVM vs. symbol, LO leakage, IQ imbalance, In-band emission, spectrum flatness,
  - Output RF spectrum emissions,
    - Occupied bandwidth, Spectrum Emission Mask (SEM), Adjacent Channel Leakage Power Ratio (ACLR),
  - Spurious Emission,
  - Transmit Intermodulation,

- **Rx characteristics**
  - Reference sensitivity level,
  - UE maximum input level,
  - Adjacent channel selectivity,
  - Blocking characteristics,
  - Intermodulation characteristics,
  - Spurious emissions,

- **Performance requirements**
  - Demodulation FDD PDSCH (FRC),
  - Demodulation FDD PCFICH/PDCCH (FRC)

Captured in TS 36.101: User Equipment (UE) radio transmission and reception

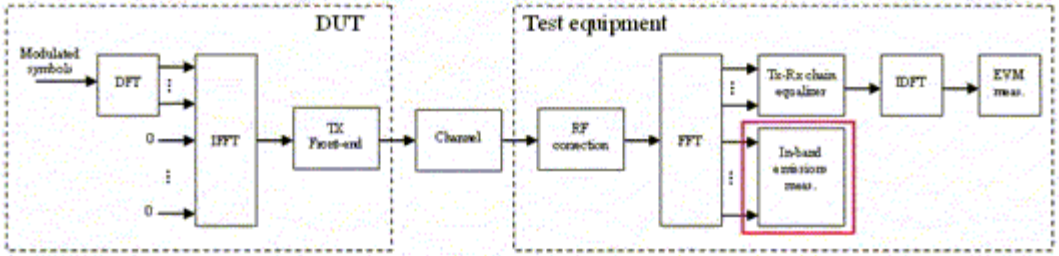
Transmit modulation



According to 3GPP specification LO leakage (or IQ origin offset) is removed from evaluated signal before calculating EVM and in-band emission.

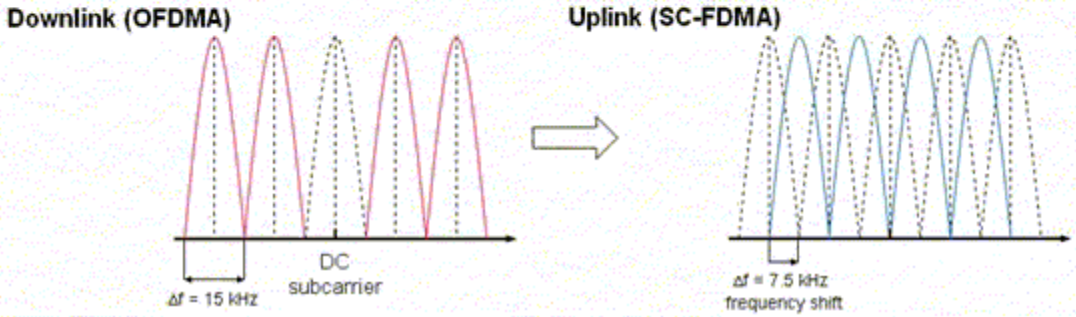
In-band emission

- Estimate the interference to non-allocated resource blocks, as the UE shares transmission bandwidth with other UE's,
  - In-band emission are measured in frequency domain are measured right after FFT, before equalization filter,
  - Measurement is defined as average across 12 subcarriers and as a function of RB offset from the edge of the allocated bandwidth,
  - Minimum requirement $\max\left[-25,(20\cdot\log_{10}EVM)-3-10\cdot(\Delta_{RB}-1)/N_{RB})\right]$



IQ component

- Also known is LO leakage, IQ offset, etc.,
- Measure of carrier feedthrough present in the signal,
- Removed from measured waveform, before calculating EVM and in-band emission (3GPP TS 36.101 V8.3.0, Annex F),
- In difference to DL the DC subcarrier in UL is used for transmission, but subcarriers are shifted half of subcarrier spacing (= 7.5 kHz) to be symmetric around DC carrier,



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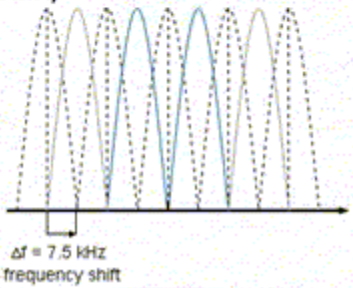
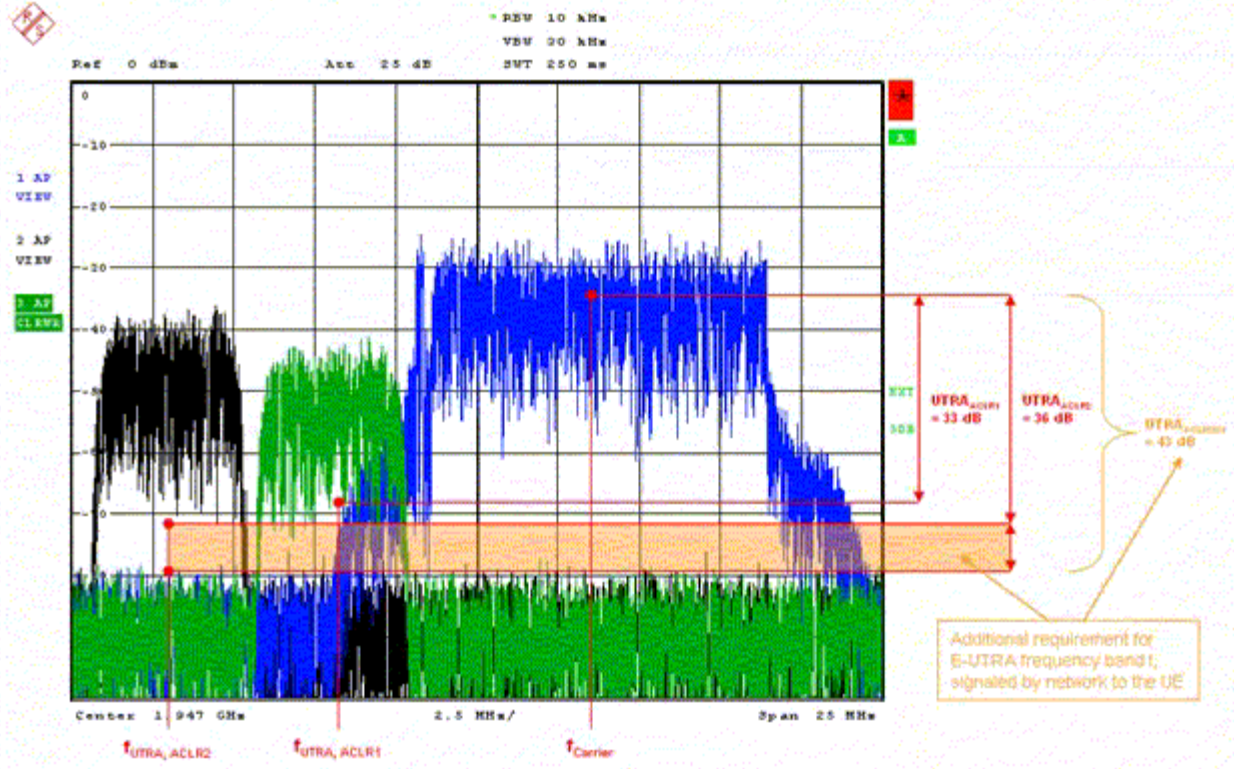
- Removed from measured waveform, before calculating EVM and in-band emission (3GPP TS 36.101 V8.3.0, Annex F),
- In difference to DL the DC subcarrier in UL is used for transmission, but subcarriers are shifted half of subcarrier spacing (= 7.5 kHz) to be symmetric around DC carrier,
- Due to this frequency shift energy of the LO falls into the two central subcarrier,

	Parameters	Relative Limit (dBc)
LO leakage	Output power > 0 dBm	-25
	-30 dBm ≤ output power ≤ 0 dBm	-20
	-40 dBm ≤ output power < -30 dBm	-10

Uplink (SC-FDMA)



ACLR measurement I



Receiver characteristics

- **Throughput shall be >95% for…**
  - Reference Sensitivity Level,
  - Adjacent Channel Selectivity,
  - Blocking Characteristics,
- **…using the well-defined DL reference channels according to 3GPP specification,**

R&S®SMx signal generators and
R&S® FSx signal analyzers

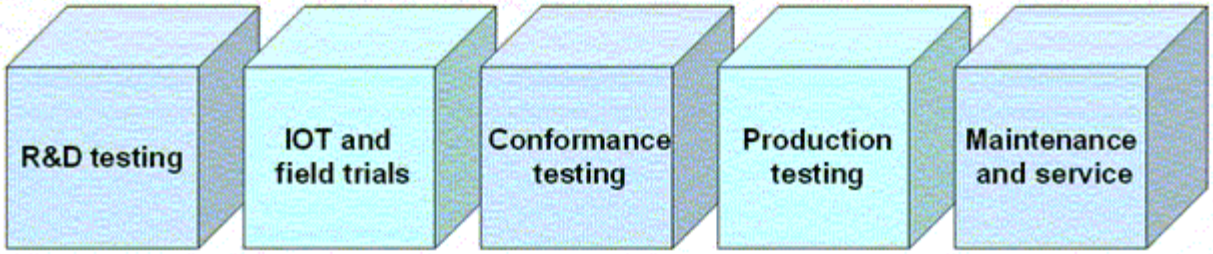
R&S®TS8980 LTE RF test system

LTE wireless device testing from R&D up to conformance

R&S®CMW500 wideband radio
communication tester

R&S®AMU200A signal generator
and fading simulator incl. MIMO

Stages of LTE terminal testing



Complementary test approaches for verifying:

Functionality and performance (RF, layer 1, protocol stack, application)	Interoperability between features and implemen-tations	Standard compliance (basis for terminal certification)	Final functional test and alignment	Basic functions and parameter test

LTE terminal interoperability testing
motivation

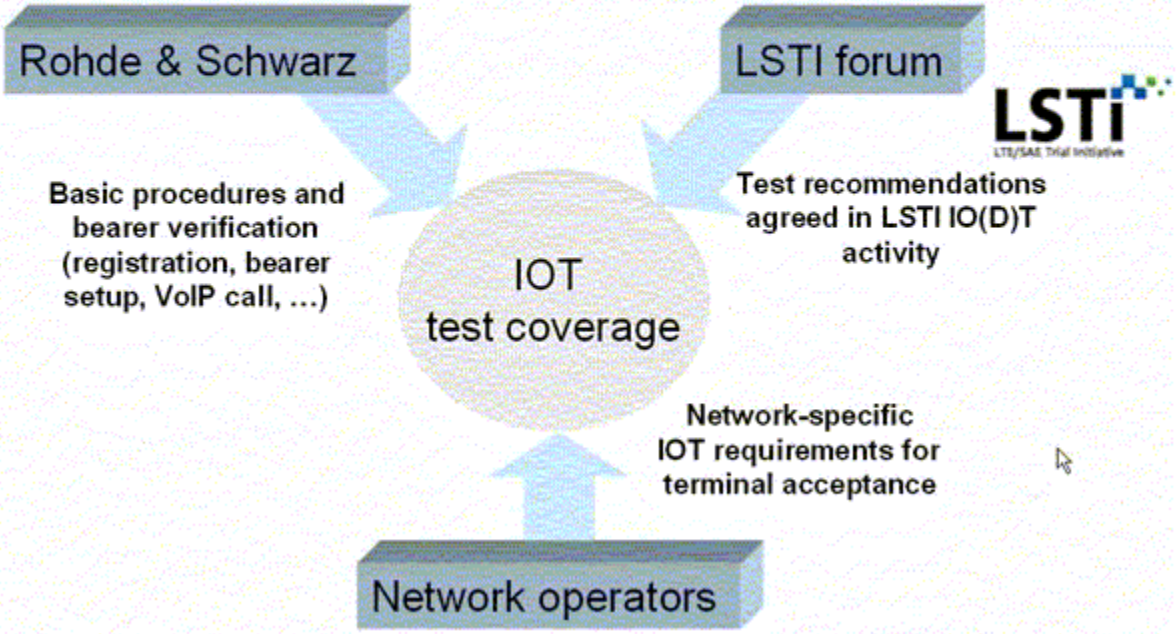
- **Interoperability testing is used to verify**
  - Connectivity of the UE with the real network (by means of base station simulators)
  - Service quality, end-to-end performance
  - Different LTE features and parametrizations
  - Interworking between LTE and legacy technologies
- **The complete UE protocol stack is tested.**
- **IOT test scenarios are based on requirements from real network operation and typical use cases.**

R&S®CMW500 wideband radio communication tester (base station simulator)

LTE terminal interoperability testing
example test scenarios

- Registration
- UE initiated detach
- Network initiated detach
- Mobile originated EPS bearer establishment
- Mobile terminated EPS bearer establishment
- Cell (re-)selection
- GUTI reallocation
- Tracking are update
- ...
- Plus: end-to-end scenarios (video streaming, VoIP, ...)
- Plus: intra-LTE mobility, inter-RAT mobility

Test scenarios for LTE terminal IOT
different sources for maximum test coverage



LTE conformance testing motivation

- **Verifying compliance of terminals to 3GPP LTE standard**
  - by validated test cases implemented on registered test platforms
  - in order to ensure worldwide interoperability of the terminal within every mobile network
- **3GPP RAN5 defines conformance test specifications for**
  - RF
  - Radio Resource Management (RRM)
  - Signalling
- **Certification organizations (e.g. GCF) define certification criteria based on RAN5 test specifications.**

R&S®CMW500 wideband radio communication tester

R&S®TS8980 LTE RF test system

LTE terminal certification
success factors

- Terminal certification as quality gateway
- Ensuring global interoperability of terminals
- Increasing reliability and performance
- Partnership between network operators, device manufacturers and test industry
- Close liaison between standardization fora and certification groups
- Harmonized processes for LTE FDD and TDD, e.g. work item structure
- LTE alignment team founded within CCF

R&S®FSH4/8 handheld
spectrum analyzer

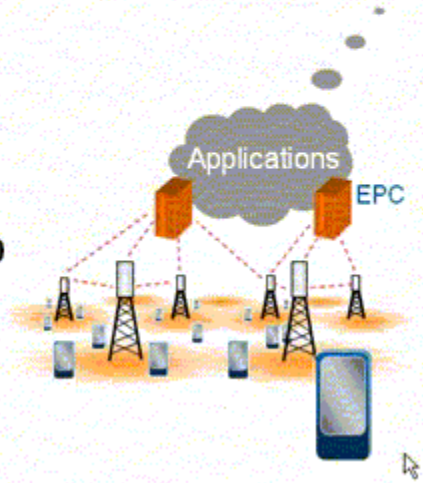
R&S®ROMES drive test software

LTE field trial testing and coverage measurements

R&S®TSMW Universal Radio
Network Analyzer

LTE field trials
requirements from different deployment scenarios

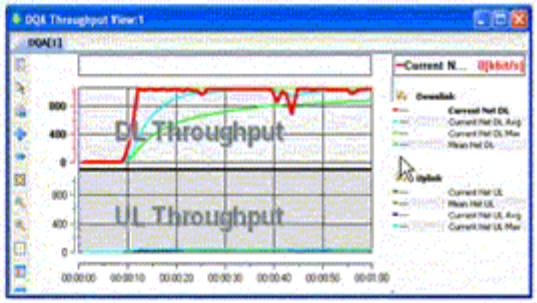
- **Bandwidths from 1.4 MHz to 20 MHz**
- **Different LTE FDD and TDD frequency bands**
- **Combination with legacy technologies (GSM/EDGE, WCDMA/HSPA, CDMA2000 1xEV-DO)**
- **Spectrum clearance and refarming scenarios**
- **Femto cell / Home eNB scenarios**



LTE field trials
scope of test tools

- **Field trials provide input for:**
  - Calibration and verification of planning tools for different deployment scenarios
  - Network optimization (capacity and quality)
  - Quality of service verification
  - Definition of Key Performance Indicators (KPIs) and verification, also from subscriber's point of view
- **Parallel use of scanners / measurement receivers for comparison with UE and base station behaviour**
- **Support of IOT activities**

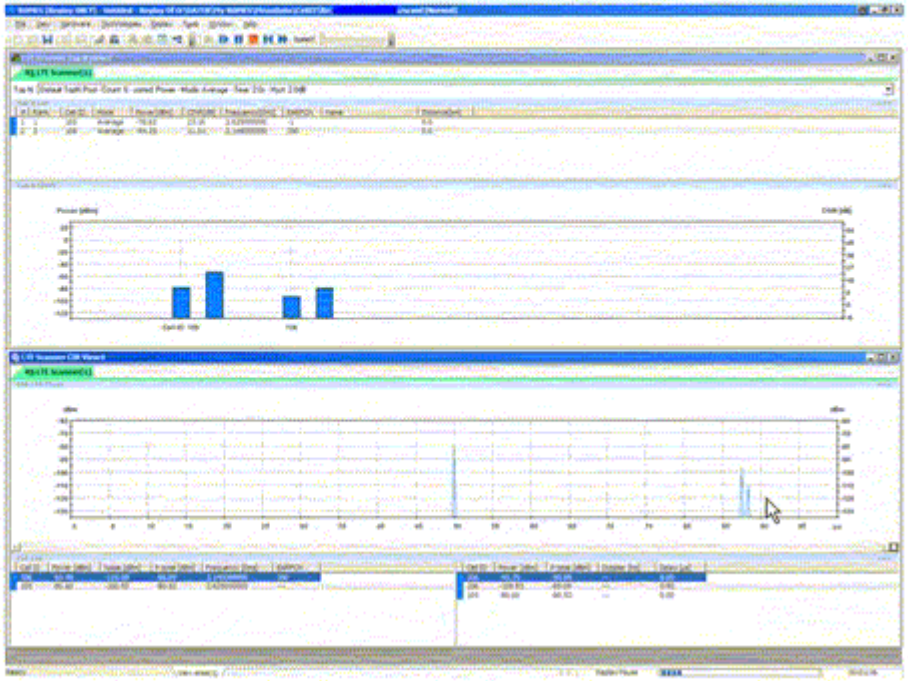
R&S®TSMW Network Scanner and ROMES Drive Test Software



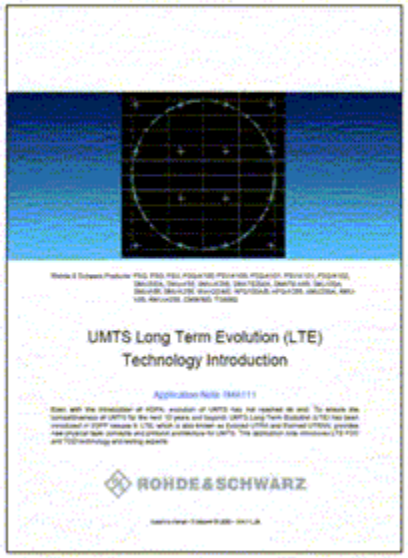
Example result from the field
scanner measurements for LTE

TopN list of all pilots
with Power and SINR

Channel Impulse Response
for Multi Path Reflections and check of Cyclic Prefix



Would you like to know more?



LTE application notes from Rohde & Schwarz