R&S®TSMx
LTE-M scanning
Application Note

Products:

R&S®TSME6-K35	R&S®TSMW-K35
R&S®TSMA6-K35	R&S®ROMES4ACD
R&S®TSME-K35	R&S®ROMES4
R&S®TSMA-K35	

This application note summarizes the R&S®TSMx scanner features for LTE-M measurements.

Note:

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Application Note

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5.2019 – Version 8NT4_0e

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1 Introduction

LTE-M (also known as Cat M1) is a machine type communication (MTC) standard for IoT applications, specified by 3GPP. 3GPP defines several standards for IoT, where each standard addresses different use-cases. The standards differ in data rate, complexity, mobility and features. Data sources for IoT, such as sensors are expected to be maintenance-free for a long time, which puts strong requirements on the battery life. Complex radio technologies (e.g. commercial LTE with carrier aggregation and MIMO 4x4) are very battery consuming and over engineered for transmitting status data for a few times per hour, day or month, where data rate is less important. In this case, it is the reliability of data transmission, which counts. This is the point where cellular IoT standards benefit in direct comparison with traditional LTE.

During the last years, NB-IoT (also known as Cat NB1) became very popular. The data transmission in NB-IoT is very robust which increases the link budget between the NB-IoT module and the eNodeB. NB-IoT makes use of several retransmissions in up- and downlink and additional power boosting in downlink. It is designed to be as simple as possible with lowest data rates and no "seamless" mobility, which turns it into the most battery saving LTE based IoT standard, but misses important features such as mobility and voice / VoLTE.

LTE-M is a bit more complex, but brings additional features. The most important ones are mobility and higher data rates, which allows e.g. continuous container tracking, whereas NB-IoT is recommended for stationary use cases such as smart power or water meters. The maximum achievable data rate in LTE-M is one Mbit / s. LTE-M also makes use of retransmissions but it is not power boosted compared to traditional LTE.

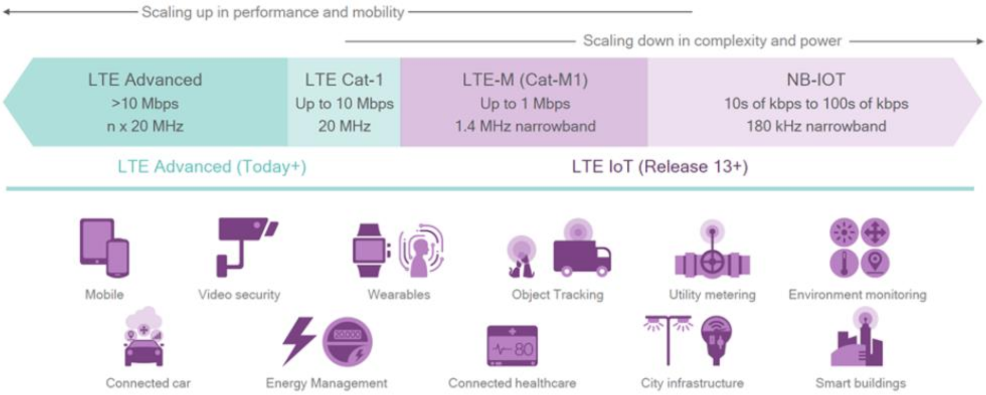


Figure 1: Use cases of LTE and cellular LTE based IoT technologies.

It is not possible to deploy LTE-M without deploying traditional LTE carrier. Guard-band and Stand-alone deployment modes (as known from NB-IoT) are not available. LTE-M requires the synchronization and reference signals of LTE, but occupies just 1.4 MHz (= 6 PRBs). Resource blocks occupied with LTE-M transmissions are not available for LTE data transmissions, which reduces the capacity for mobile broadband applications running on LTE. The scheduling of LTE-M data transmission on the LTE carrier can be very flexible, because LTE-M uses the feature of "frequency hopping / RF retuning for retransmissions" to overcome impacts from fading, interference or LTE traffic.

"Frequency hopping / RF retuning" can take place between defined LTE-M narrowbands, with dedicated 6 PRBs each narrowband. Table 1 to Table 4 shows LTE-M narrowbands for 5, 10, 15, and 20 MHz LTE carriers.

Narrowband Index	0	1	2	3
RB Index	0, 1, … 5	6, 7, … 11	13, 14, … 18	19, 20, … 24

Table 1: LTE-M narrowbands for a 5 MHz LTE carrier

Narrowband Index	0	1	2	3	4	5	6	7
RB Index	1…6	7…12	13…18	19…24	25…30	31…36	37…42	43…48

Table 2: LTE-M narrowbands for a 10 MHz LTE carrier

Narrowband Index	0	1	2	3	4	5
RB Index	1…6	7…12	13… 18	19…24	25…30	31…36
	6	7	8	9	10	11
	38…43	44…49	50… 55	56…61	62…67	68…73

Table 3: LTE-M narrowbands for a 15 MHz LTE carrier

Narrowband Index	0	1	2	3	4	5	6	7
RB Index	2…7	8…13	14…19	20…25	26…31	32…37	38…43	44…49
Narrowband Index	8	9	10	11	12	13	14	15
RB Index	50…55	56…61	62…67	68…73	74…79	80…85	86…91	92…97

Table 4: LTE-M narrowbands for a 20 MHz LTE carrier

Figure 2 shows an example of RF retuning. The LTE-M transmission is retuned to a different LTE-M narrowband. RF Retuning takes a short period of time and therefore leads to a few lost OFDM symbols. The innermost six PRBs, which are used for primary and secondary synchronization signals are excluded from LTE-M data transmission as they contain static information for cell acquisition.

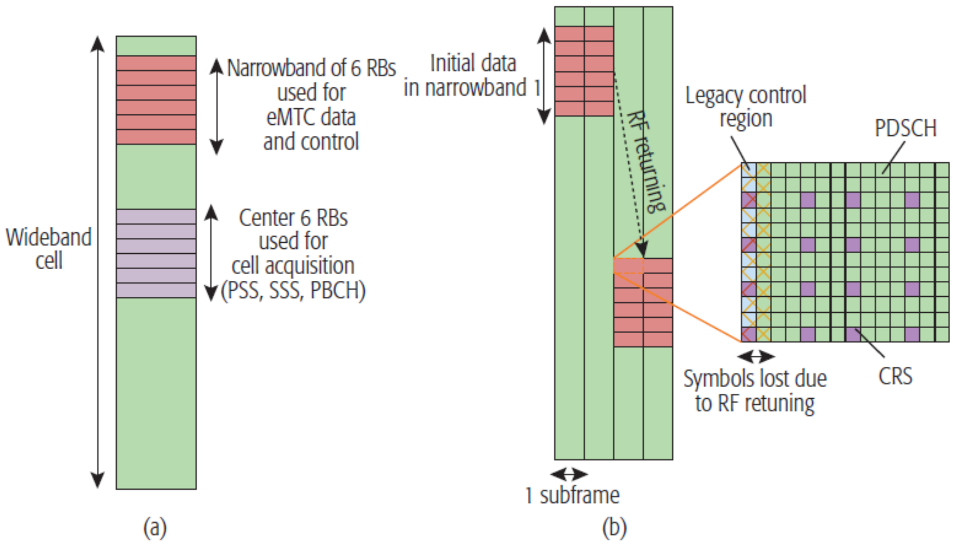


Figure 2: Frequency hopping / RF retuning in LTE-M for PDSCH content (e.g. SIB1-BR)

RF retuning with retransmissions is an efficient mechanism to overcome fading and react on spontaneous changes coming from the RF environment (SINR, RSRQ and RSRP) which is very common in LTE networks. Figure 3 shows the evolution of RS-SINR over time (3 sec.) and all resource blocks on both eNB-Tx-ports. The RS-SINR is changing rapidly due to LTE traffic, interference from neighbor cells, fading and many other reasons.

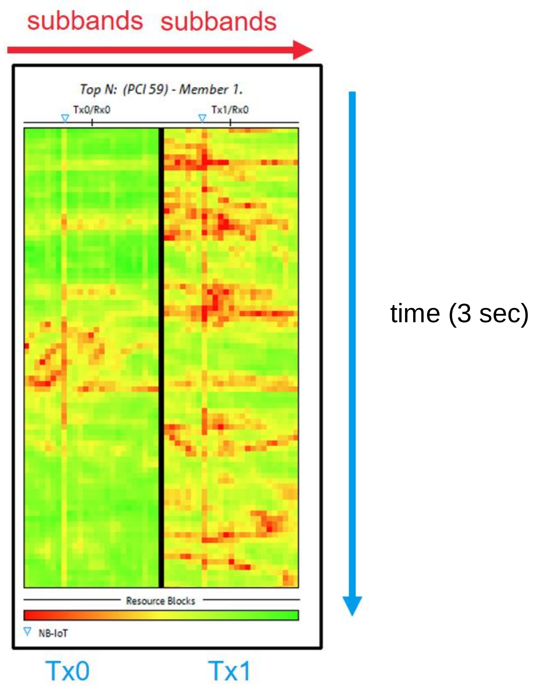


Figure 3: Fast-changing RF conditions during a couple of seconds (RS-SINR) on both antenna ports (Tx 0, Tx1) over all LTE resource blocks / sub bands. Green color indicates areas (over resource blocks and time) of good SINR, red color indicates areas of bad SINR.

Summary of LTE-M features:

→ The maximum channel bandwidth is reduced to 1.08MHz, or six LTE resource blocks.

→ 15dB coverage enhancement compared to Cat 0 / LTE devices resulting in a maximum coupling loss of 155.7dB. This enhancement is primarily due to repetition of the PDSCH, PBCH and M-PDCCH channels beyond one subframe. LTE-M uses two coverage enhancement modes A (maximum number of repetitions: 32) and B (maximum number of repetitions: 2048) with QPSK modulation (very robust modulation scheme).

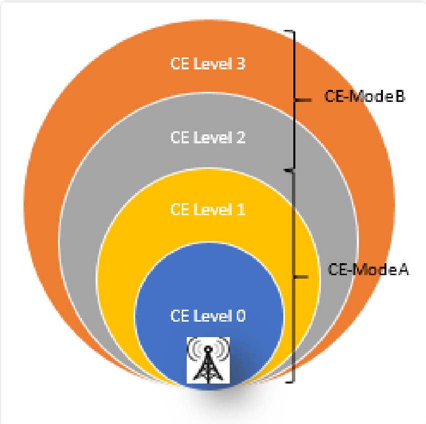


Figure 4: Coverage enhancement modes in LTE-M (resulting in a different number of PDSCH, SIB1-BR retransmissions).

→ Just like in legacy LTE, the LTE-M standard uses the center six resource blocks for cell search and random access. The PSS, SSS, PBCH (MIB), and PRACH (physical random access channel) from LTE is reused.

→ LTE-M can be served by LTE cells with much larger bandwidth. For this reason, narrowbands (6RB frequency segments) are defined within which LTE-M can be transmitted. See later section.

→ LTE-M uses a single receive antenna with peak data rates are around one Mbit / s and it supports half duplex operation

→ LTE-M reuses cell specific reference signals (CRS) from LTE and can be deployed in SISO, MIMO 2x2 and MIMO 4x4 network (fully compatible) LTE networks. LTE-M uses one single receive antenna at the LTE-M module.

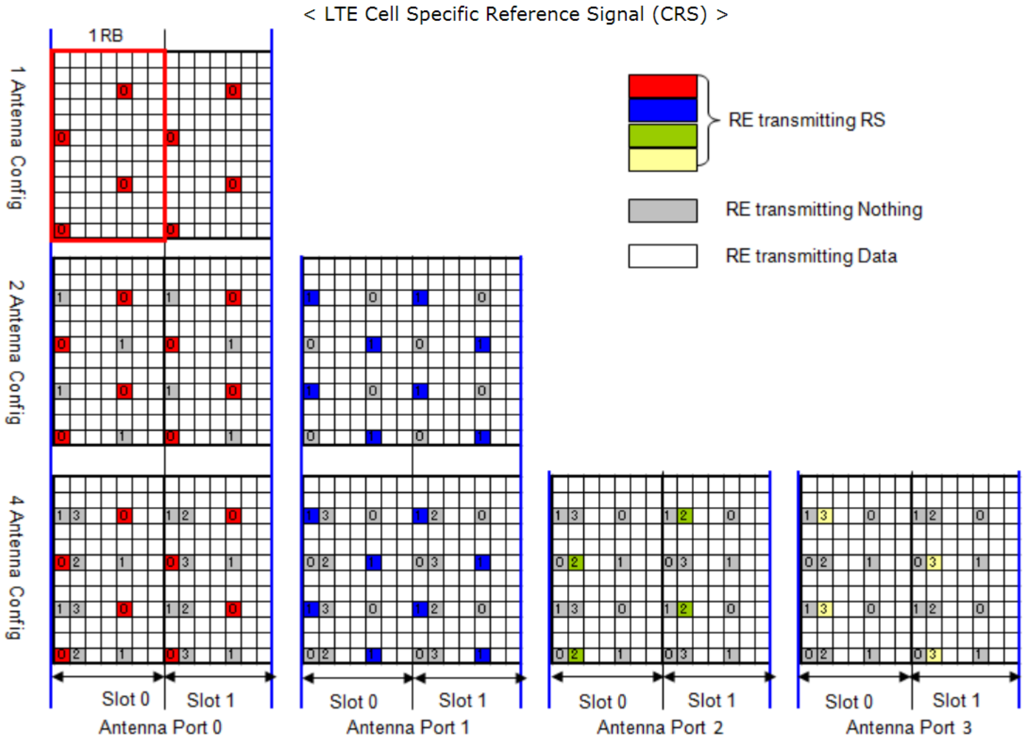


Figure 5: Cell specific reference signals in LTE in SISO, MIMO 2x2 and MIMO 4x4 configuration (with Tx port specific reference signals).

2 LTE-M measurements

2.1 Detecting LTE-M

LTE carriers do not necessarily support LTE-M. The LTE-M rollout is still ongoing and the operators have to invest in upgrading their LTE infrastructure to support LTE-M. It is expected, that the number of LTE-M deployments is increasing, as NB-IoT (which is already deployed by many operators) addresses different IoT use cases (see chapter 1). In theory, LTE-M and NB-IoT can coexist within one single LTE carrier.

Operators will preferably use lower frequencies to deploy LTE-M (700, 800, 900 MHz) for better (indoor) penetration.

The presence of LTE-M can be detected by checking the LTE MIB of the LTE carrier.

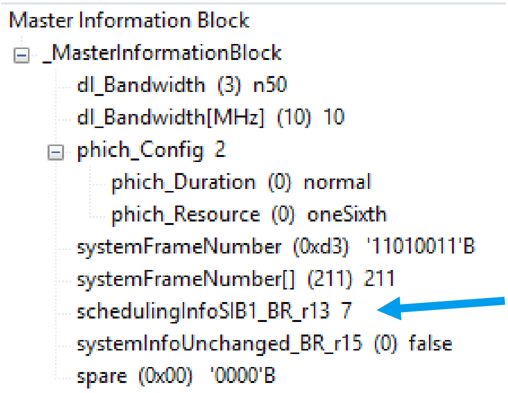


Figure 6: MIB content when LTE-M is enabled (per cell ID).

The scheduling information of SIB1-BR (BR = bandwidth reduced) with values unequal to zero indicates the presence of LTE-M in that particular LTE carrier / cell.

For better clarity, R&S®ROMES4 provides a basic summary of LTE network configurations in the LTE Scanner BCH View and provides an LTE-M indicator (per cell ID / PCI). Furthermore, the scanner detects the LTE carrier downlink bandwidth to determine the LTE-M narrowbands.

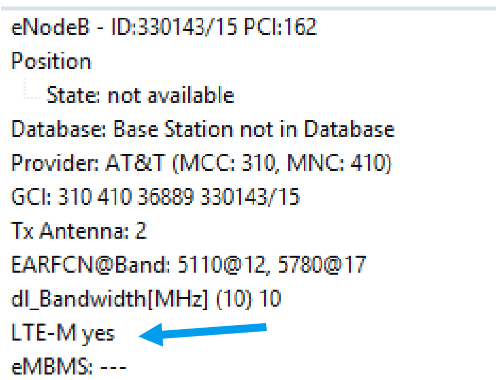


Figure 7: Summary of basic LTE network configurations per cell ID with LTE-M indicator.

In LTE / LTE-M networks, not every PCI necessarily supports LTE-M. In the case of such a "mixed" deployment, LTE MIBs of several cells do not include the LTE-M flag / SIB1-BR info. The scanner is able to determine if LTE-M is present after fully decoding the LTE MIB. In practice, the SINR threshold for LTE MIB demodulation is much higher than for the initial PCI decoding and RF measurements on a LTE cell. The same applies for the downlink bandwidth and therefore for the narrowband distribution. Both, downlink bandwidth and LTE-M flag are read from the LTE MIB. Waiting for a full LTE MIB demodulation of all discovered PCIs would significantly affect the scanners' performance (especially SINR dynamic range). Therefore, R&S®ROMES4 provides settings to help the scanner with LTE-M narrowband and downlink bandwidth detection.

The setting is called Demodulation Configuration / Bandwidth Control Recovery Mode and can be found in the LTE channel advanced settings:

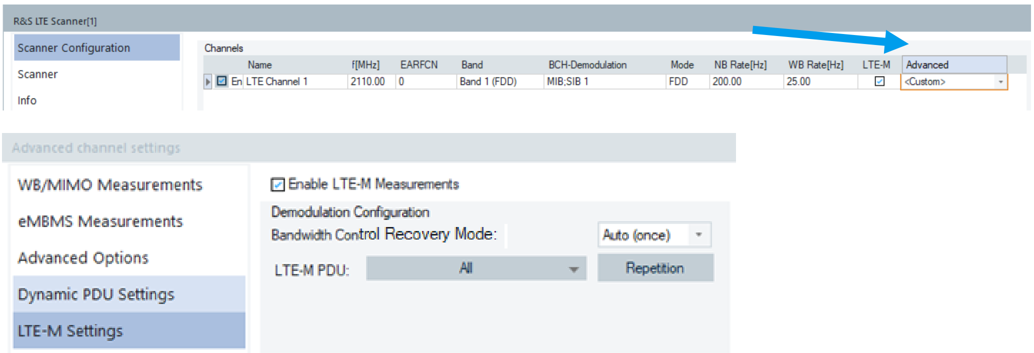


Figure 8: Configuration dialogs for bandwidth and LTE-M detection.

The following settings are available:

Auto (once, default setting): LTE MIB decoding is shared for all PCIs. It is sufficient to detect one LTE MIB with a LTE-M flag and a certain bandwidth per LTE channel. LTE-M narrowband measurements will be performed for all PCIs based on the initially detected bandwidth and with a LTE-M flag or the LTE MIB not yet decoded. Once the LTE MIB is decoded with the result ‘LTE-M not available’, LTE-M narrowband measurements will be canceled for the relevant PCIs. Auto (once) is the default setting; it is the best setting for networks, with (close to) network wide LTE-M coverage and constant LTE bandwidth across the network.

Auto (tracking): LTE MIB decoding is required for each PCI. LTE-M narrowband measurements will start after discovering the LTE-M flag and the measurement is adjusted to the bandwidth for each PCI. This limits the performance of the scanner due to the fact the demodulation SINR threshold is around 0 dB. Auto (tracking) is the best setting for LTE-M networks with punctual LTE-M coverage and / or different LTE bandwidth across the network. It reduces the scanner performance (SINR threshold for initial detection) but it does not perform LTE-M narrowband measurements unless LTE-M is detected without doubt.

Bandwith selection: LTE-M narrowband measurements are performed at a fixed carrier bandwidth and no matter whether the LTE-M flag in LTE MIB is present.

The best way to get an overview in terms of LTE carriers and LTE-M availability is the ACD (Automatic Channel Detection). From R&S®ROMES4 release 19.0, the ACD view uses the information from the LTE MIB to flag LTE carriers, which support LTE-M.

The ACD can be configured by using the ACD wizard in R&S®ROMES4.

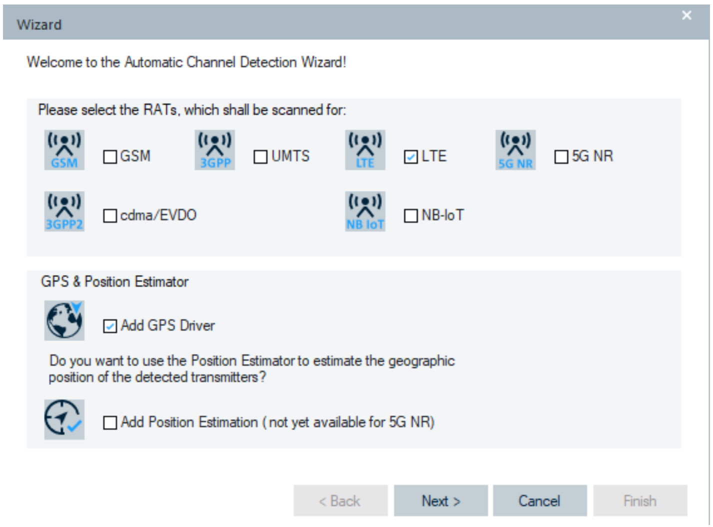


Figure 9: ACD configuration wizard in R&S®ROMES4

For detecting LTE-M, the RAT LTE has to be enabled in the wizard. Of course, any other technology can be selected to discover e.g. 5G NR or UMTS carriers in parallel. After that, R&S®ROMES4 guides you through the wizard with band and frequency selections for each technology. LTE-M has to be enabled independently from the LTE ACD in the LTE scanner configuration page for the virtual ACD channel configuration.

Figure 10: Enable LTE-M scans in the LTE scanner configuration page

Figure 11 shows the result of the automatic channel detection (ACD) for LTE and LTE-M networks. The LTE-M ACD is sensitive on one single PCI with LTE-M enabled.

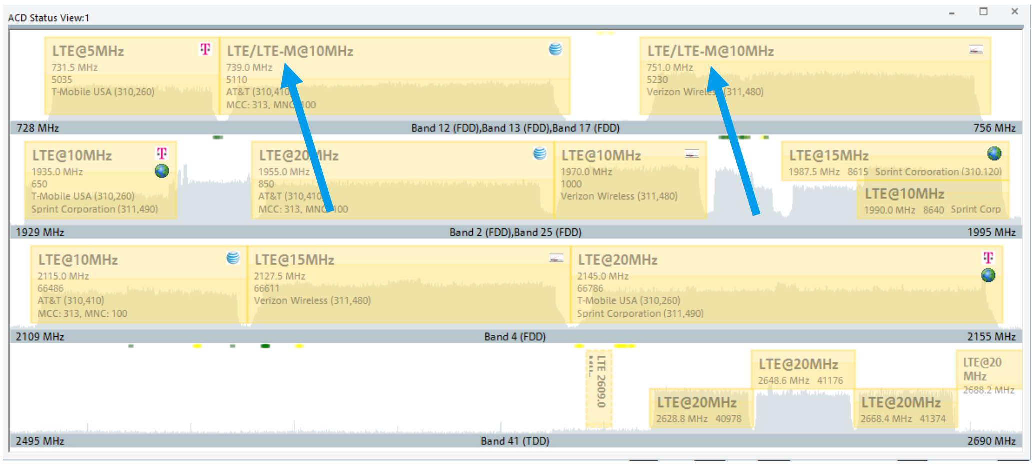


Figure 11: ACD result in ACD view of R&S®ROMES4. LTE carriers with LTE-M enabled are marked with LTE/LTE-M.

Another alternative to detect LTE-M availability is the LTE Scanner Top N View. From 19.0 release, R&S®ROMES4 provides an LTE-M indicator in the LTE Scanner Top N View (has to be selected in the Top N View configuration page).

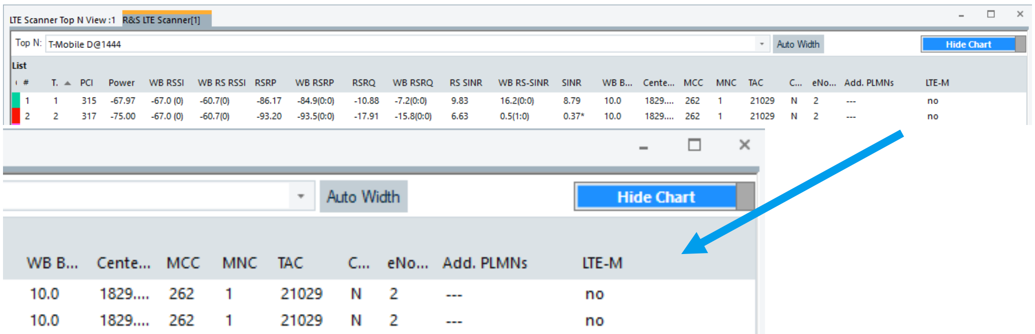


Figure 12: LTE-M indicator in the LTE Scanner Top N View. In this particular case, LTE-M is not available.

2.2 LTE / LTE-M synchronization signal measurements

As explained in chapter 1, LTE-M does not provide its own synchronization signals. LTE-M modules use legacy LTE synchronization signals in the innermost six resource blocks for cell acquisition and synchronization. Therefore, the synchronization signal RF results from the LTE scanner can be reused for synchronization signals measurements. LTE-M is indicated by "yes" in the LTE-M column.

#	TopX	PCI	Power	RSRP	RSRQ	SINR	Center Frequency	LTE-M
1	1	163	-68.88	-88.98	-13.13	9.22	739.00	yes
2	2	164	-81.50	-102.04	-26.19	-12.96*	739.00	yes
3	3	264	-84.40	-102.21	-28.25	-19.06*	739.00	yes

Figure 13: LTE Scanner Top N View configured to measure synchronization signal RF parameters (RSRP, RSRQ, SINR).

2.3 LTE-M RF measurements over all LTE-M narrowbands

The LTE-M scanner provides average and total RF results over all LTE-M narrowbands and narrowband specific results. Average / total results are ideal for coverage measurements providing single RSSI, RSRP, SINR and RSRQ measurements per detected (LTE-M) PCI.

#	TopX	PCI	RSSI	Total BR-RSSI	Avg BR-RSRP	Avg BR-SINR	Avg BR-RSRQ	EARFCN	Center Frequency
1	1	163	-66.46	-62.71	-92.77	8.49	-13.24	5110	739.00
2	2	55	-66.46	-62.42	-105.99	-15.48	-26.75	5110	739.00
1	1	391	-50.83	-52.04	-83.29	13.11	-14.43	5230	751.00
2	2	282	-50.83	-51.57	-97.00	-18.13	-28.61	5230	751.00

Figure 14: LTE-M average measurements over all LTE-M narrowbands.

"Avg" in the signal name indicates average results across all LTE-M narrowbands, while the "Total BR-RSSI" is a total value across all narrowbands. It indicates the total power of all OFDM symbols that carry cell specific reference signals. Total and average measurement parameters are explained in Table 5.

RF parameter	Definition
RSSI	Received signal strength indicator. The RSSI measurement provides the total average power of the received waveform within the signal bandwidth. It will contain signal power from the signal of interest, noise and interferers.
Total BR-RSSI	Reference signal received signal strength indicator. Total across all narrow bands. This measurement provides the total average power of OFDM symbols that carry cell specific reference signals.
Avg BR-RSRP	Reference signal received power. Average across all narrow bands. This measurement represents the linear average over the power contributions (mW) of the resource elements that carry cell specific LTE reference signals (CRS) within the measurement bandwidth. By default, the CRS from eNodeB antenna port 0 is are used for this purpose, but CRS of other ports may also be used for the measurement.
Avg BR-RSRQ	Reference signal received quality. Average across all narrow bands. This measurement is computed as the following ratio. Remember that the RS-RSSI measurement extends over the full signal bandwidth. RSRQ = (NRB · RSRP) / RS-RSSI
Avg BR-SINR	Reference signal carrier to interference and noise ratio. This measurement is a ratio of the power of the LTE-M signal from a particular cell and noise and interference that are present. This measurement is performed at the resource elements occupied by cell specific reference signals.

Table 5: RF parameters and their definitions of average and total measurements across all LTE-M narrowbands.

2.4 LTE-M RF measurements per LTE-M narrowband

LTE-M measurements per LTE-M narrowband are available for all detected (LTE-M) PCIs. Narrowband specific measurements unveil differences in power (RSSI, RSRP), SINR and quality between different narrowbands, which come from fading, LTE(-M) traffic and interference. The higher the difference between the LTE-M narrowbands, the higher the benefit from RF retuning / frequency hopping. Narrowband measurements are performed for each LTE-M PCI and can be visualized in the LTE-M scanner Top N View by selecting one PCI with a left-click. Figure 15 shows LTE-M narrowband results with a difference of roughly 7 dB in SINR between the narrowbands. RF retuning / frequency hopping could help the LTE-M module to use narrowbands with positive SINRs successful data sessions. Optimizing the hopping sequence and increasing the number of repetitions can significantly improve the link budget.

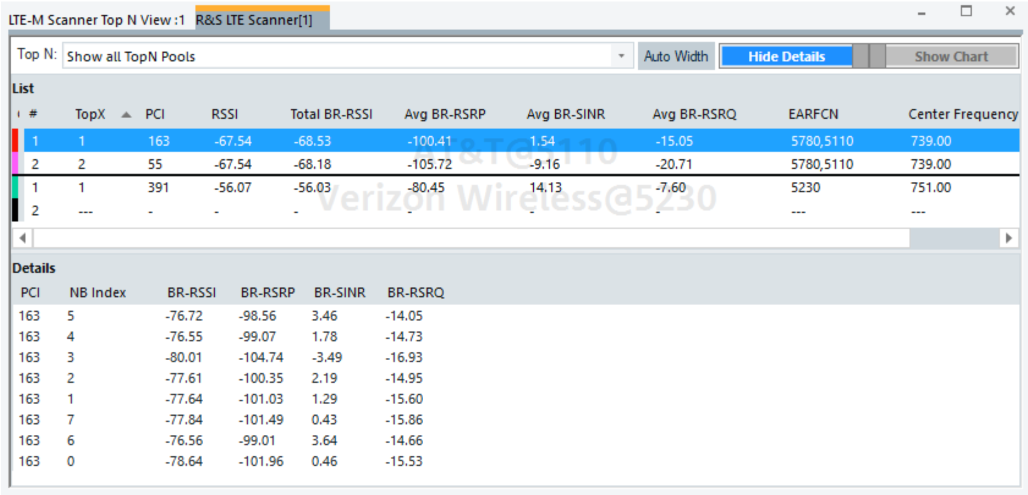


Figure 15: Narrowband measurement results on PCI 163 (in the 'Details' section of the LTE-M scanner Top N View).

The signal structure in R&S®ROMES follows the same approach of PCIs with average / total and narrowband specific measurements. Each LTE-M Top N Pool member provides its own narrowband results.

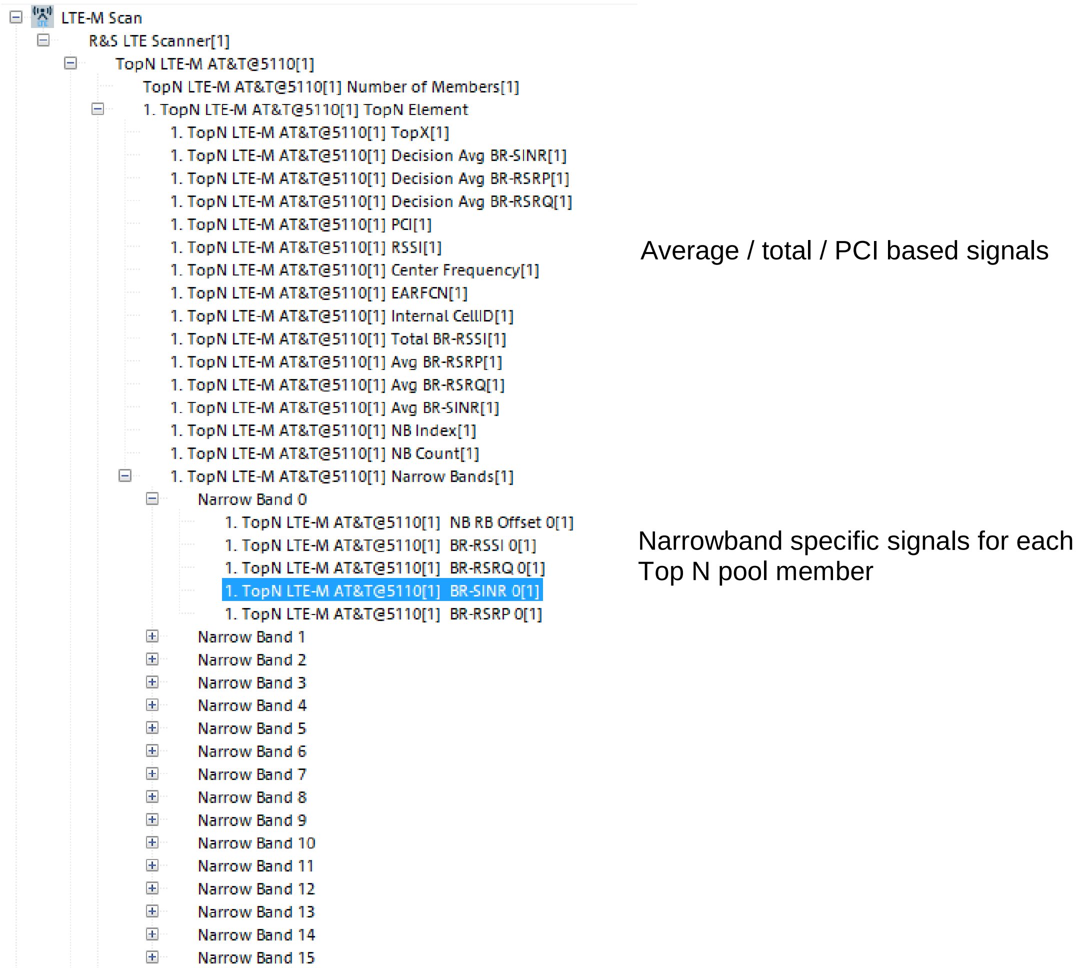


Figure 16: LTE-M scanner signal structure with narrowband results for each LTE-M Top N Pool member (only NB 0 branch is expanded).

Table 6 summarizes all narrowband specific RF measurements in R&S®ROMES4.

RF parameter	Definition
NB index	Narrowband index (starting from 0).
NB count	The number of narrowbands for a given cell.
Narrow band Resource Block Offset	Narrowband resource block offset to locate the LTE-M narrowband
BR-RSSI	Reference signal received signal strength indicator. This measurement provides the total average power of OFDM symbols that carry cell specific reference signals within the particular LTE-M narrowband.
BR-RSRP	Reference signal received power. This measurement represents the linear average over the power contributions (mW) of the resource elements that carry cell specific LTE reference signals (CRS) within the measurement bandwidth and the particular LTE-M narrowband. By default, the CRS from eNodeB antenna port 0 is are used for this purpose, but CRS of other ports may also be used for the measurement.
BR-RSRQ	Reference signal received quality. This measurement is computed as the following ratio. Remember that the RS-RSSI measurement extends over the full signal bandwidth. RSRQ = (NRB · RSRP) / RS-RSSI Referece signals of the particular narrowband are taken into account.
BR-SINR	Reference signal carrier to interference and noise ratio. This measurement is a ratio of the power of the LTE-M signal from a particular cell and noise and interference that are present. This measurement is performed at the resource elements (within the particular LTE-M narrowband) occupied by cell specific reference signals (within the particular LTE-M narrowband).

Table 6: Narrowband specific RF parameters and their definitions.

2.5 LTE-M MIB and SIB-BR demodulation results

LTE-M broadcasts its own SIB messages. The SIB1 message in LTE-M is called SIB1-BR (with BR = bandwidth reduced). If the network is configured for retransmissions and therefore RF retuning, the SIB1-BR is transmitted within different narrowbands during different sub frames. For SIB1-BR demodulation, the scanner follows the SIB1-BR (re-) transmissions and decodes the content.

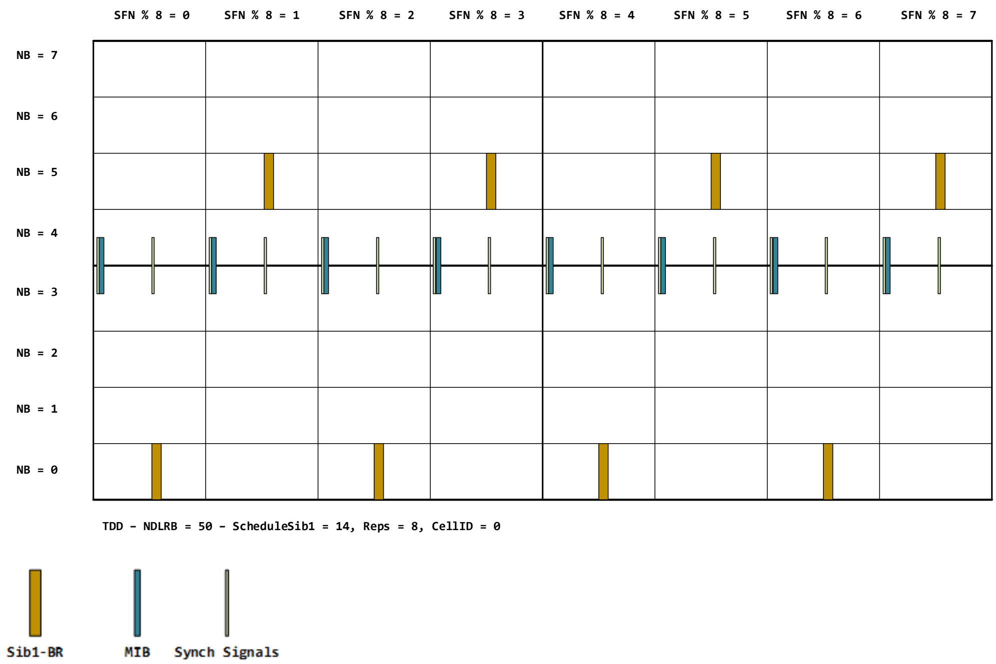
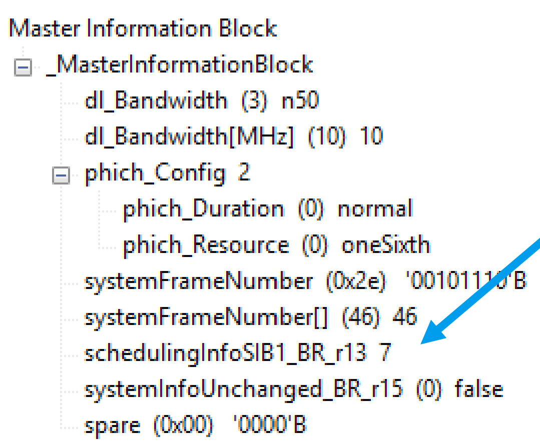


Figure 17: MIB, SIB1-BR and synchronization signal transmissions over several subframes and narrowbands in LTE-M.

PDSCH / SIB1-BR retransmissions can be detected from the SIB1-BR scheduling info r13, which broadcasted in the LTE MIB. The LTE MIB was extended by the SIB1-BR schedule information in Release 13.



Value of *schedulingInfoSIB1-BR-r13*	Number of PDSCH repetitions
0	N/A
1	4
2	8
3	16
4	4
5	8
6	16
7	4
8	8
9	16
10	4
11	8
12	16
13	4
14	8
15	16
16	4
17	8
18	16
19-31	Reserved

Figure 18: Detecting the number of LTE-M SIB1-BR retransmissions from LTE MIB.

Parameters for cell identification can be found in SIB1-BR. It includes MNC, MCC, cell identity, basic reselection and scheduling information.

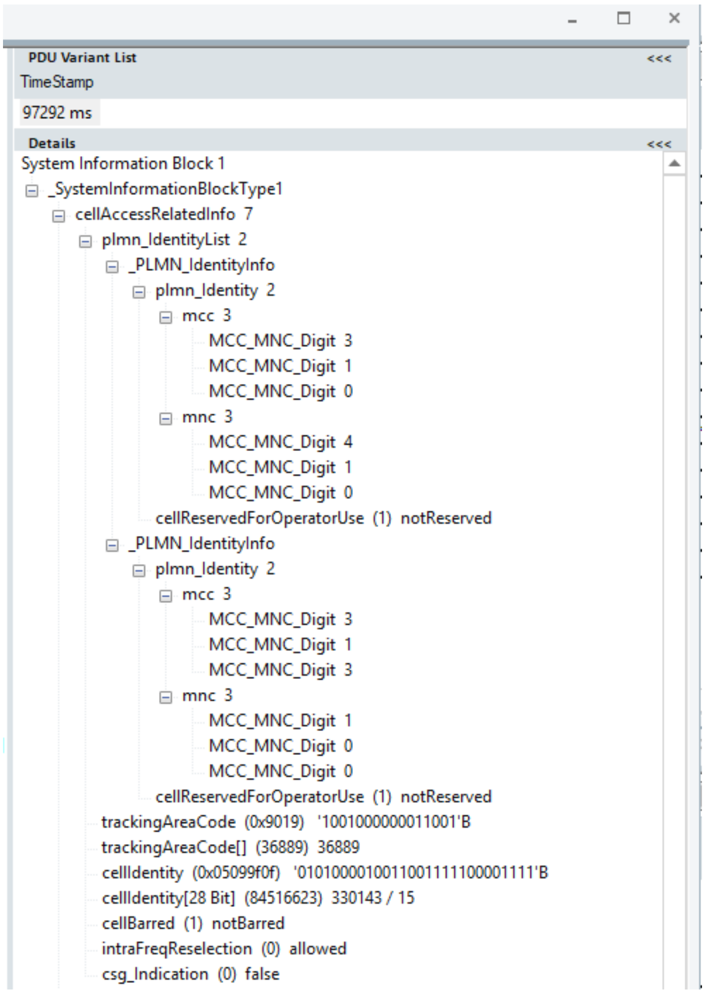


Figure 19: SIB1-BR content (cell defining information): Special case: Second MCC, MNC.

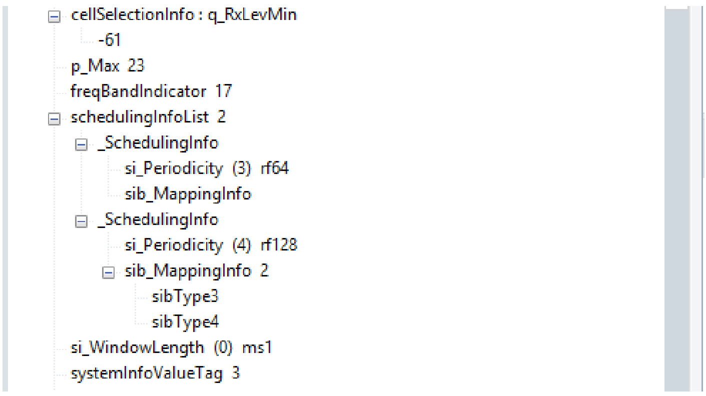


Figure 20: SIB1-BR content (basic reselection information)

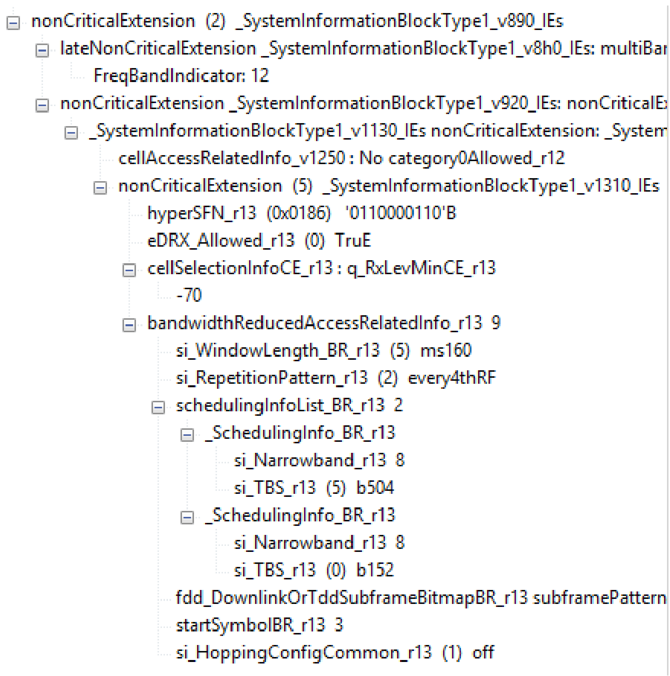


Figure 21: SIB1-BR content (scheduling information)

Figure 19 to Figure 21 show an example of SIB1-BR. Figure 19 shows an example of multiple-PLMN configuration (which indicates network sharing), where one physical carrier has two identities in terms of mobile network and mobile country code (MNC, MCC).

3 Literature

3GPP specification: 36211, 36212, 36331, 36330

4 Ordering Information

Designation	Type	Order No.
Ultracompact drive test scanner (350 - 6000 MHz)	R&S®TSME6	4900.0004.02
Autonomous mobile network scanner (350 - 6000 MHz)	R&S®TSMA6	4900.8005.02
Ultracompact drive test scanner (350 - 4400 MHz)	R&S®TSME	1514.6520.02
Autonomous mobile network scanner (350 - 4400 MHz)	R&S®TSMA	1514.6520.20
Radio Network Analyzer (30 MHz - 6000 MHz)	R&S®TSMW	1503.3001.03
LTE-M scanning on TSME6	R&S®TSME6-K35	4900.2465.02
LTE-M scanning on TSMA6	R&S®TSMA6-K35	4901.0208.02
LTE-M scanning on TSME	R&S®TSME-K35	4900.7473.02
LTE-M scanning on TSMA	R&S®TSMA-K35	4900.7467.02
LTE-M scanning on TSMW	R&S®TSMW-K35	4900.7480.02
Simultaneous measurement in all bands	R&S®TSME6-KAB	4900.2107.02
Simultaneous measurement in all bands	R&S®TSMA6-KAB	4901.0708.02
Drive test software	R&S®ROMES4	1117.6885.04
R&S®TSME6 driver for R&S®ROMES4 drive test software	R&S®ROMES4T1E	1117.6885.82
R&S®ROMES4 driver, automatic channel detection	R&S®ROMES4ACD	1506.9869.02

Glossary

A

ACD: Automatic Channel Detection (automatically searches for carriers of several technologies on air, e.g. LTE, 5G NR SSBs, WCDMA, GSM… and delivers a channel template for ultra-fast scanner configuration)

B

BR: Bandwidth-Reduced; indicator for LTE-M / bandwidth reduced services based on LTE

C

CE (level): Coverage extension level; coverage and link budget extension is achieved by different network configurations; e.g. stable modulation schemes and repetitions

CRS: Cell specific reference signals: Reference signals in LTE and LTE-M; their position in time and frequency domain is known; they are "always-on" and they are used channel measurements and estimations.

E

eMTC: Enhanced machine type communication; other term for LTE-M

eNB: eNode B; LTE base stations

I

IoT: Internet of Things; "Things are connected to the internet" by using sensors and cloud-based data platforms.

L

LTE: Long Term Evolution; radio access technology optimized for mobile broadband applications with data rates up to one GBit / s.

LTE-M: LTE-Machine type; Optimized radio access technology for machine type communication based on LTE.

M

MCC: Mobile Country Code; unique code for each country (three digits)

MIB: Master Information Block; broadcasted information for LTE(-M) cell identification.

MIMO: Multiple Inputs, Multiple Outputs; Data transmission on several independent layers to enhance the spectral efficiency (e.g. used in LTE networks).

MNC: Mobile Network Code; unique code for each network.

Multi-PLMN: Multi public land mobile network; one physical cells carries several MCCs and MNCs for network sharing (same physical resources for different operators).

N

NB-IoT: Narrowband IoT; simple and battery saving radio access technology for connecting things (e.g. sensors) to the internet.

P

PDSCH: Physical Downlink Shared Channel; main downlink channel dynamically allocated to users

PRB: Physical Resource Block; physical unit of the LTE spectrum.

Q

QPSK: Quadrature Phase Shift Keying; very robust modulation scheme relying on phase shifting.

R

RB: → see PRB.

RSRP, RSRQ, RSSI → see Table 5 and Table 6

S

SIB: System Information Block; broadcasted information per LTE-M cell to obtain the network configuration

SISO: Single Input Single Output; one antenna at receiver and transmitter is used.

SINR: → see Table 5 and Table 6

T

Tx Port: Physical antenna element / port at the eNode B.

V

VoLTE: Voice over LTE; allows high quality voice calls over a LTE network with a simultaneous high speed data session

Rohde & Schwarz

The Rohde & Schwarz electronics group offers innovative solutions in the following business fields: test and measurement, broadcast and media, secure communications, cybersecurity, radiomonitoring and radiolocation. Founded more than 80 years ago, this independent company has an extensive sales and service network and is present in more than 70 countries.

The electronics group is among the world market leaders in its established business fields. The company is headquartered in Munich, Germany. It also has regional headquarters in Singapore and Columbia, Maryland, USA, to manage its operations in these regions.

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Sustainable product design

- Environmental compatibility and eco-footprint
- Energy efficiency and low emissions
- Longevity and optimized total cost of ownership

Certified Quality Management ISO 9001

Certified Environmental Management ISO 14001

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PAD-T-M: 3573.7380.02/03.00/EN

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