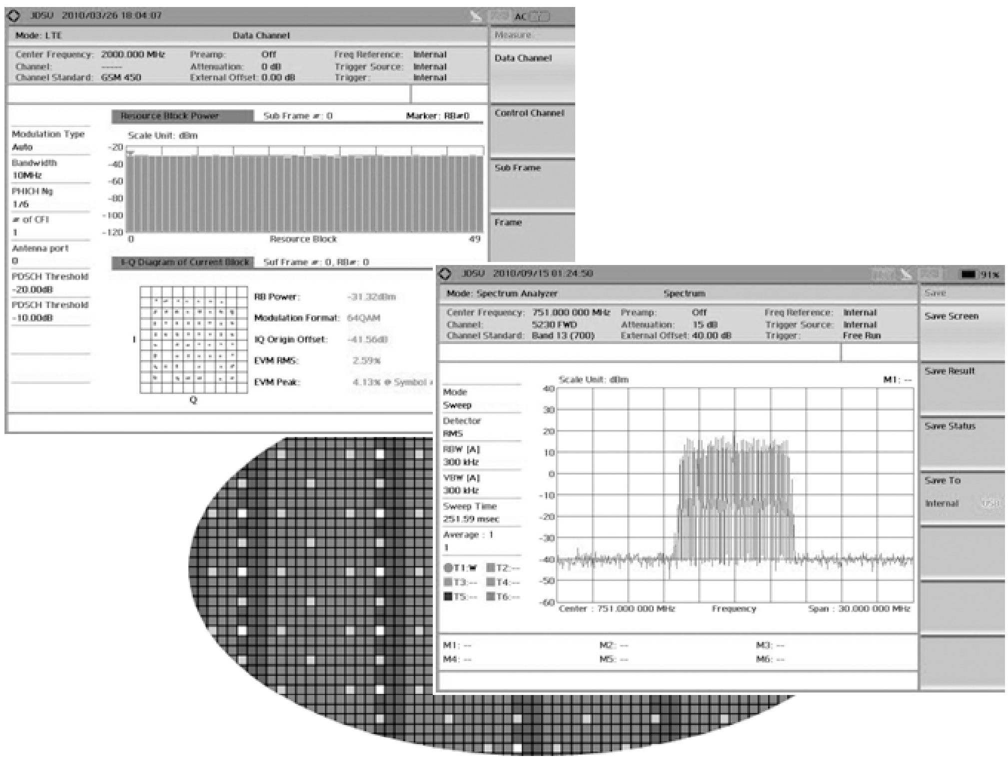
JDSU

Application Note

Base Station Analyzer

LTE PHY Layer Measurement Guide



Contents

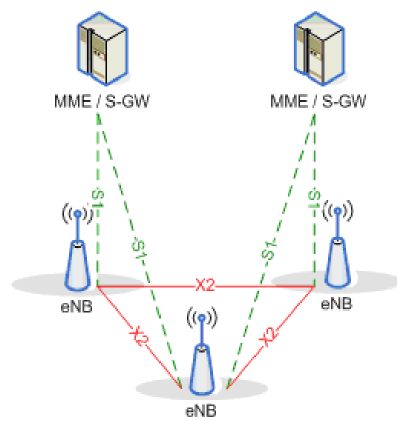
Understanding LTE

Overall Architecture

The LTE overall architecture consists of cell sites or E-UTRAN Node Bs (eNBs), mobility management entities (MME), and serving gateways (S-GW). The eNBs provide the user interface towards mobile phones and devices, and they are interconnected with each other through X2 interfaces; and, they are connected to the backhaul or evolved packet core (EPC) through S1 interfaces.

Serving gateway (S-GW) functions:

- local mobility anchor for inter-eNB handover, inter-3GPP mobility
- E-UTRAN idle mode downlink packet buffering and initiation of network-triggered service request procedure
- lawful interception
- packet routing and forwarding
- transport-level packet marking in the uplink and the downlink
- accounting on user and QCI granularity for inter-operator charging
- UL and DL charging per UE, PDN, and QCI.



Mobility management entity (MME) functions:

- NAS signaling, security; AS security control; inter-CN node signaling for mobility between 3GPP access networks
- idle-mode UE reachability
- tracking area list management
- PDN GW and serving GW selection
- MME selection for handovers with MME change
- SGSN selection for handovers to 2G or 3G 3GPP access networks
- roaming
- authentication
- support for ETWS message transmission.

eNB functions:

- radio resource management: radio bearer control, radio admission control, connection mobility control; dynamic allocation of resources to UEs in both uplink and downlink (scheduling); measurement for mobility and scheduling; scheduling and transmission of earthquake and tsunami warning system (ETWS) messages (originated from the MME)
- routing of user plane data towards serving gateway
- paging messages (originated from the MME)
- broadcast information (originated from the MME or O&M)
- load balancing; inter-cell interference, handover, error indication.

Figure 1. LTE Overall Architecture (Ref. 2)

LTE Physical Layer

The multiple access schemes in LTE use orthogonal frequency division multiple access (OFDMA) with a cyclic prefix (CP) in the downlink and single carrier frequency division multiple access (SC-FDMA) with a cyclic prefix in the uplink.

The resource allocation in the frequency domain takes place with a resolution of 180 kHz resource blocks both in uplink and downlink. The uplink user specific allocation is continuous; it enables single-carrier transmission while the downlink uses resource blocks which are spectrum independent. LTE enables spectrum flexibility where the transmission bandwidth can be selected between 1.4 MHz and 20 MHz depending on the available spectrum. The following figure shows an example of frequency allocation in LTE downlink and uplink transmission. The 20 MHz bandwidth downlink in a 2 x 2 MIMO configuration can provide a downlink data rate up to 150 Mbps, and 300 Mbps with 4 × 4 MIMO configuration. The uplink peak data rate is 75 Mbps.

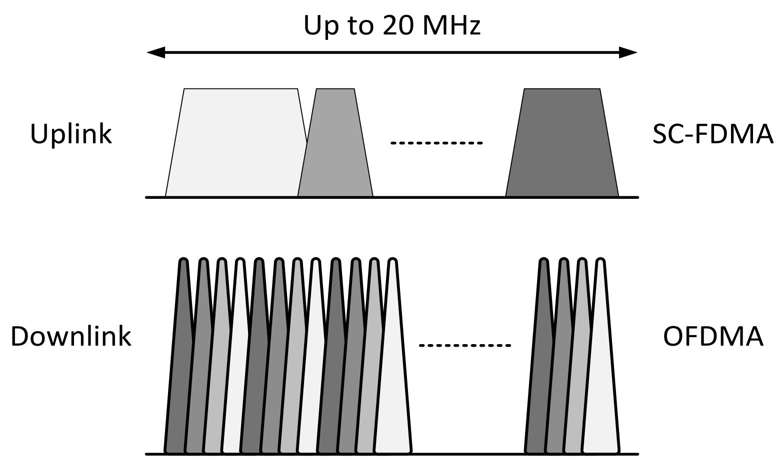


Figure 2. LTE multiple access schemes

LTE Downlink

The LTE downlink can be set on six different frequency profiles, as follows:

Channel bandwidth [MHz]	**1.4**	**3**	**5**	**10**	**15**	**20**
Transmission bandwidth [MHz]	1.08	2.7	4.5	9	13.5	18
Transmission bandwidth [RB]	6	15	25	50	75	100

Table 1. LTE downlink profiles

The difference between transmission bandwidth and channel bandwidth is shown in the following figure.

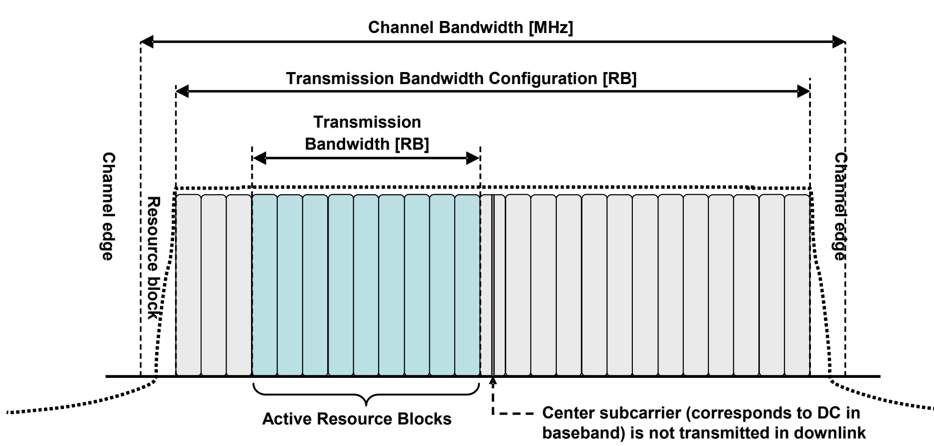


Figure 3. LTE channel bandwidth and transmission bandwidth (Ref. 3)

Due to unused subcarriers, the transmission bandwidth is smaller than the channel bandwidth. For example, in frequency domain, each resource block occupies 180 kHz. Therefore, a 5 MHz signal can transmit 27.78 RB (5 MHz/180 kHz). However, 25 resource blocks are used for the 5 MHz LTE channel and it occupies 4.5 MHz bandwidth. For that reason, transmission bandwidth is the reference for all measurements excluding occupied bandwidth measurements.

In general, each subcarrier is allocated in a 15 kHz interval except for multicast broadcast single frequency network (MBSFN) transmission which is allocated in a 7.5 kHz interval. Therefore, each resource block with 12 subcarriers occupies a bandwidth of 180 kHz (12 subcarriers x 15 kHz). A resource block is the minimum allocation unit for system resource allocation and the transmission bandwidth is obtained by the number of resource blocks (n) multiplied by 180 kHz (bandwidth per RB).

Frame Structure

The following figure shows the frame structure of an LTE signal (FDD). In the time domain, one LTE frame has a 10 ms period and consists of 20 slots of 0.5 ms each. A subframe is defined as two consecutive slots.

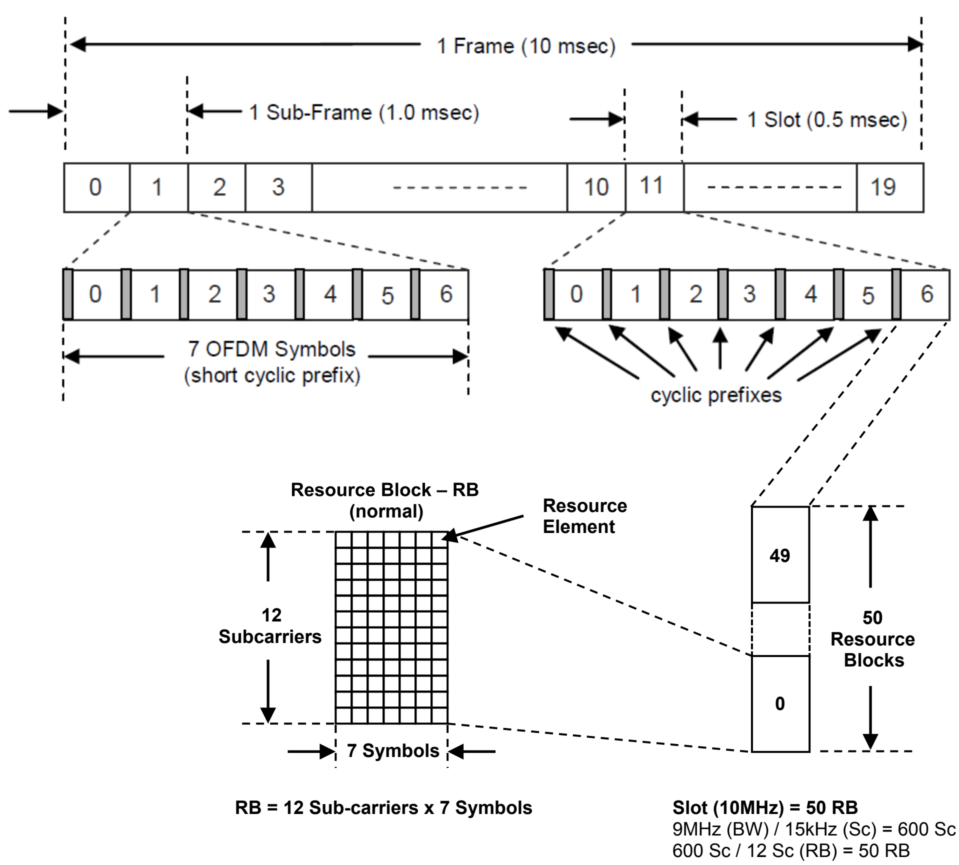


Figure 4. LTE frame structure

The representation of a LTE timeslot in a configuration of Δf at 15 kHz and the cyclic prefix (CP) is normal. One slot is represented as a resource block (RB) consisting of 7 symbols by 12 subcarriers, or 84 resource elements (RE) per RB. Therefore, one LTE frame consists of 20 slots each allocating 1 RB (7 symbols) in time and 10 MHz channel bandwidth transports 50 RB (9 MHz/15 kHz/12), or 1000 RB per frame (50 x 20), or 84000 RE per frame (1000 x 84), where an RE is the minimum unit for data allocation and power control.

The basic frame parameters for each LTE channel bandwidth are summarized in the following table.

Channel Bandwidth [MHz]	**1.4**	**3**	**5**	**10**	**15**	**20**
Transmission BW [MHz]	1.08	2.7	4.5	9	13.5	18
Subframe duration			0.5 ms			
Subcarrier spacing			15 KHz			
Sampling frequency [MHz]	1.92 (1/2x3.84)	3.84	7.68 (2x3.84)	15.36 (4x3.84)	23.04 (6x3.84)	30.72 (8x3.84)
FFT size (No. of effective T_S/symbol)	128	256	512	1024	1536	2048
T_S period (us)	0.5208	0.2604	0.1302	0.0651	0.0434	0.0326
No of T_S/time slot	960	1,920	3,840	7,680	11,520	15,360

* T_S period= 1/(sampling frequency)
* No. of T_S/time slot = 0.5 ms/T_S period

Table 2. LTE frame parameters

The indication "T_S" corresponds to the bit information that can be transferred in a LTE downlink signal where the Ts value in a timeslot is directly proportional to the data throughput of each channel bandwidth.

Resource Block

Resource blocks (RB) are used to describe the mapping of physical channels to resource elements (RE). The representation of a timeslot, symbol, and RE are shown in the following figure.

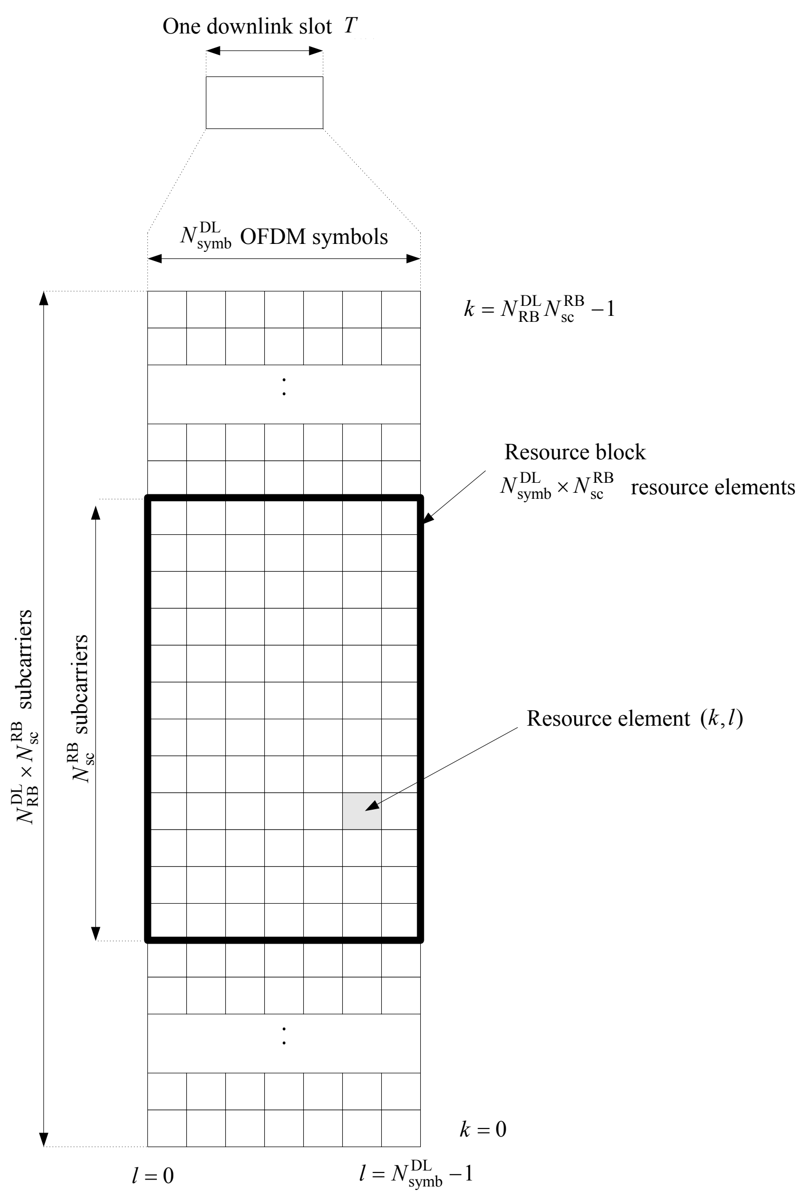


Figure 5. Downlink resource grid (Ref. 1)

A physical resource block (RB) is defined as set of 7 consecutive OFDM symbols in the time domain and 12 consecutive subcarriers (SC) in the frequency domain. Therefore, a physical resource block contains 84 RE and represents one slot in the time domain of 180 kHz in the frequency domain.

Configuration		N_{SC}^{RB}	N_{symb}^{DL}
Normal cyclic prefix	Δf = 15 kHz	12	7
Extended cyclic prefix	Δf = 15 kHz		6
	Δf = 7.5 kHz	24	3

Table 3. Physical resource blocks parameters (Ref. 1)

The number of OFDM symbols in a slot depends on the cyclic prefix length and subcarrier spacing configured.

In case of multi-antenna transmission, there is one resource grid defined per antenna port. An antenna port is defined by its associated reference signal. The set of antenna ports supported depends on the reference signal configuration in the cell:

- cell-specific reference signals, associated with non-MBSFN transmission, support a configuration of one, two, or four antenna ports
- MBSFN reference signals, associated with MBSFN transmission, are transmitted on antenna port 4
- UE-specific reference signals are transmitted on antenna port 5.

Cyclic Prefix

Similar to Mobile WiMAX, LTE also implements cyclic prefix (CP) to form a symbol. Data symbol periods become shorter as the data rate becomes larger since the symbol period is inversely proportional to the data rate or 1/(data rate). As the symbol period shortens, the inter-symbol interference (ISI) is more severe in a wireless environment where there are many multipath (reflective) signals which have different time delays. It is known that ISI negatively affects the beginning part of each symbol and distorts data.

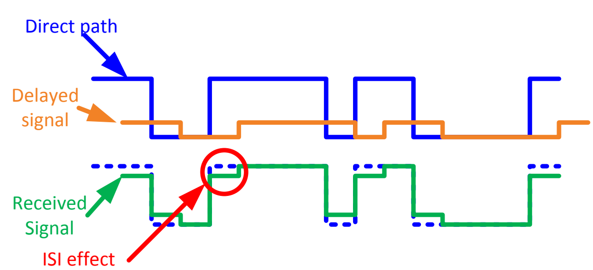


Figure 6. Distortion of received signal due to ISI

A relatively long OFDM symbol period should resist the multipath environment. In addition, LTE adds the CP in front of every symbol by copying the latter part of each symbol. By increasing the CP ratio (CP length to effective symbol length), the system becomes more robust against multipath however it results in a decreased data capacity.

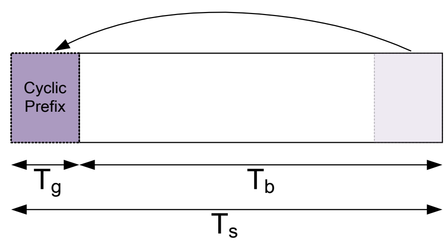


Figure 7. Symbol structure

When the subcarrier spacing is 15 kHz, the length of the effective symbol becomes 1/ 15 kHz ≈ 66.7 μs. For normal CP, one timeslot is composed of 7 symbols and as a result a LTE frame consists of 140 symbols (7 symbols x 20 slots). Hence the sum of all effective symbol lengths in a LTE frame is 9.33 ms.

Extended CP consists of 6 symbols for a timeslot with a subcarrier interval of 15 kHz and 3 symbols for a timeslot with a subcarrier interval of 7.5 kHz. The time length of the CP depends on the subcarrier allocation and CP type. The number of T_S increases as the channel bandwidth increases. The following table illustrates the T_S and CP allocation for each channel bandwidth.

Bandwidth	**Configuration (downlink)**		**Length of CP**	
			T_s	**μsec**
20 MHz	normal CP	Δf = 15K Hz	160 for = 0	5.208
			144 for = 1,2,..,6	4.6875
	extended CP	Δf = 15 KHz	512 for = 0,1,…,5	16.667
		Δf = 7.5 KHz	1024 for = 0,1,2	33.333
15 MHz	normal CP	Δf = 15 KHz	120 for = 0	5.208
			108 for = 1,2,..,6	4.6875
	extended CP	Δf = 15 KHz	384 for = 0,1,…,5	16.667
		Δf = 7.5 KHz	768 for = 0,1,2	33.333
10 MHz	normal CP	Δf = 15 KHz	80 for = 0	5.208
			72 for = 1,2,..,6	4.6875
	extended CP	Δf = 15 KHz	256 for = 0,1,…,5	16.667
		Δf = 7.5 KHz	512 for = 0,1,2	33.333
5 MHz	normal CP	Δf = 15 KHz	40 for = 0	5.208
			36 for = 1,2,..,6	4.6875
	extended CP	Δf = 15 KHz	128 for = 0,1,…,5	16.667
		Δf = 7.5 KHz	248 for = 0,1,2	33.333
3 MHz	normal CP	Δf = 15 KHz	20 for = 0	5.208
			18 for = 1,2,..,6	4.6875
	extended CP	Δf = 15 KHz	64 for = 0,1,…,5	16.667
		Δf = 7.5 KHz	128 for = 0,1,2	33.333
1.4 MHz	normal CP	Δf = 15 KHz	10 for = 0	5.208
			9 for = 1,2,..,6	4.6875
	extended CP	Δf = 15 KHz	32 for = 0,1,…,5	16.667
		Δf = 7.5 KHz	64 for = 0,1,2	33.333

Table 4. CP lengths and T_s occupation for each channel bandwidth

The symbol lengths and T_s numbers for different channel bandwidths are illustrated in the following figure. The number of T_s for each OFDMA symbol depends on the FFT size. Thus, the length of T_S is proportional to the sampling rate.

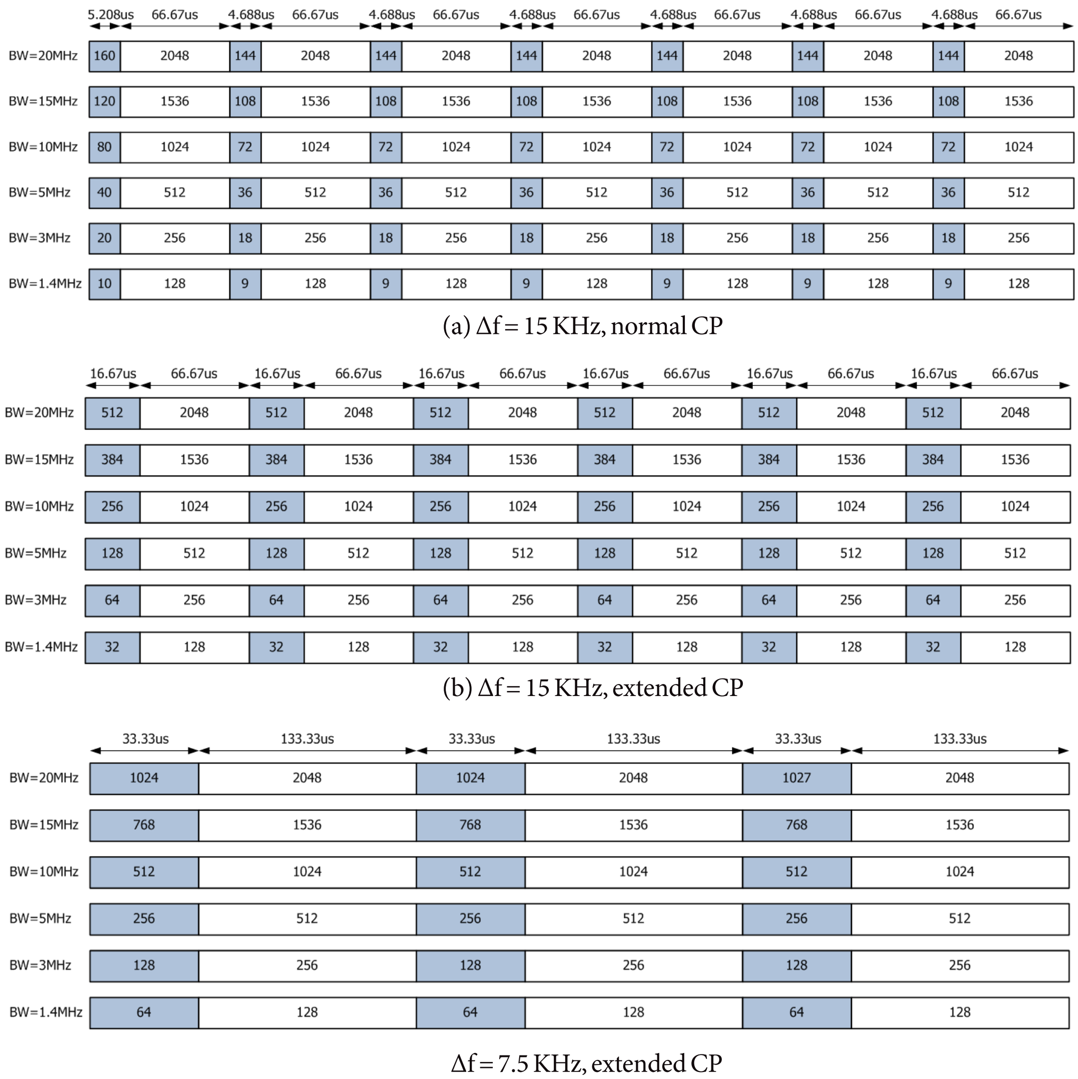


Figure 8. Number of T_s for each OFDMA symbol

Downlink Physical Channel

A downlink physical channel corresponds to a set of resource elements (RE) carrying information originating from higher layers and its interface is defined in 36.212 and 36.211. The following physical channels are defined for LTE PHY downlinks.

- Physical downlink shared channel (PDSCH)
- Physical control format indicator channel (PCFICH)
- Physical downlink control channel (PDCCH)

- Physical hybrid ARQ channel(PHICH)
- Physical broadcast channel (PBCH)
- Physical multicast channel (PMCH)

Physical Downlink Shared Channel (PDSCH)

The user data in the downlink is carried on the physical downlink shared channel (PDSCH). The same 1 ms long and 180 kHz wide resource block is the fundamental data scheduling unit. Thus, the user data rate is dependent on the number of resource blocks for a specific user. The base station (eNB) carries out the resource allocation based on the channel quality indicator (CQI) from the LTE terminal. The shared channel (PDSCH) is time shared with the control channel (PDCCH) in the first timeslot of each subframe and occupies the second timeslot where the subframe does not transmit broadcast (PBCH), primary synchronization (PSS), or secondary synchronization (SSS).

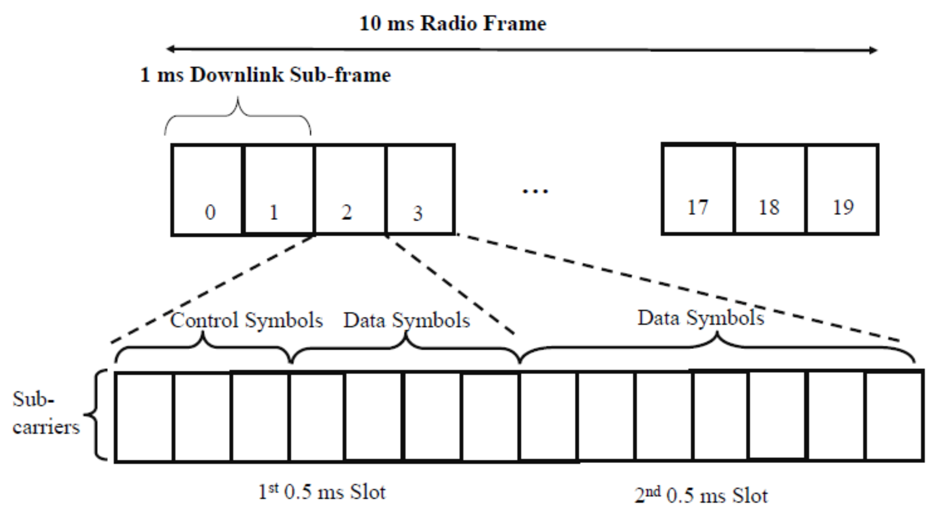


Figure 9. Downlink slot structure for bandwidth above 1.4 MHz

The modulation format of PDSCH channels may be QPSK, 16 QAM or 64 QAM. In the PDSCH channel, reference signals are allocated regularly enabling channel estimation and minimizing overhead.

Physical channel	Modulation schemes
PDSCH	QPSK, 16QAM, 64QAM

Table 5. PDSCH modulation schemes

Physical Control Format Indicator Channel (PCFICH)

The purpose of PCFICH is to indicate how many OFDMA symbols are reserved for control information. This can vary between one and three for each 1 ms subframe. The use of dynamic signaling capability allows the system to support both a large number of low data rate users as well as to provide sufficiently low signaling overhead when higher data rates are used by fewer active users.

An extreme situation is illustrated in the following figure where the PDCCH allocation is changed from one symbol to three symbols. When calculating the resulting overhead, note that PDCCH is only allocated to the first 0.5 ms slot in the 1 ms subframe, thus the overhead change from 1/14 to 3/14 of the total physical layer resource space. PCFICH is always modulated with QPSK format.

Physical channel	Modulation scheme
PCFICH	QPSK

Table 6. PCFICH modulation scheme

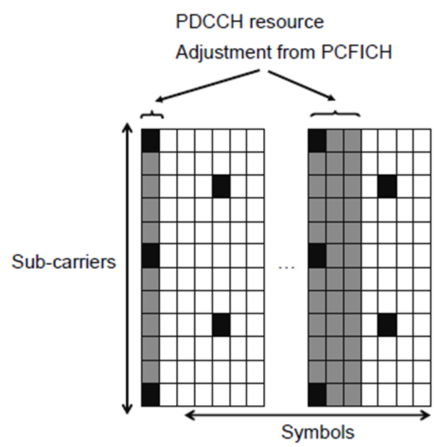


Figure 10. PDCCH resource allocations from PCFICH

Physical Downlink Control Channel (PDCCH)

The LTE user equipment will obtain from the control channel (PDCCH) the uplink and downlink resource allocations it may use. The downlink control information (DCI) mapped on the control channel (PDCCH) has different formats and depending on its size it is transmitted in one or more control channel elements (CCEs).

A CCE corresponds to nine resource element groups. Each group in turn consists of four resource elements. The control channel (PDCCH) containing shared information (PDSCH) is often referred to as the downlink assignment. The following information is carried on the downlink assignment when providing downlink resource allocation information related to primary synchronization (PSSCH):

- resource block allocation information
- the modulation and coding scheme used for downlink user data
- the HARQ process number
- the power control commands for the PUCCH.

Physical channel	Modulation scheme
PDCCH	QPSK

Table 7. PDCCH modulation scheme (Ref. 1)

Physical Hybrid ARQ indicator Channel (PHICH)

The task for the HARQ indicator channel (PHICH) is simply to indicate in the downlink whether an uplink packet was correctly received or not. The device will decode the PHICH based on the uplink allocation information received on the control channel (PDCCH).

Physical channel	Modulation schemes
PHICH	BPSK

Table 8. PHICH modulation scheme (Ref. 1)

HARQ feedback seen by the UE	PDCCH seen by the UE	UE behaviour
ACK or NACK	new transmission	new transmission according to PDCCH
ACK or NACK	retransmission	retransmission according to PDCCH (adaptive retransmission)
ACK	none	no (re)transmission, keep data in HARQ buffer and a PDDCH is required to resume retransmissions
NACK	none	non-adaptive retransmission

Table 9. Uplink HARQ operation (Ref. 2)

Physical Broadcast Channel (PBCH)

The broadcast channel (PBCH) carries the system information needed to access the system, such as random access (RACH) parameters required for initial network access and UE uplink time synchronization with the eNB. The channel is always provided with 1.08 MHz bandwidth, as shown in the following figure, so the broadcast channel (PBCH) structure is independent of the actual system bandwidth being used. With a 1.4 MHz system bandwidth, there are no resource blocks on either side of the broadcast channel (PBCH) in the frequency domain in use so effectively only six resource blocks may be used to meet the spectrum mask requirements.

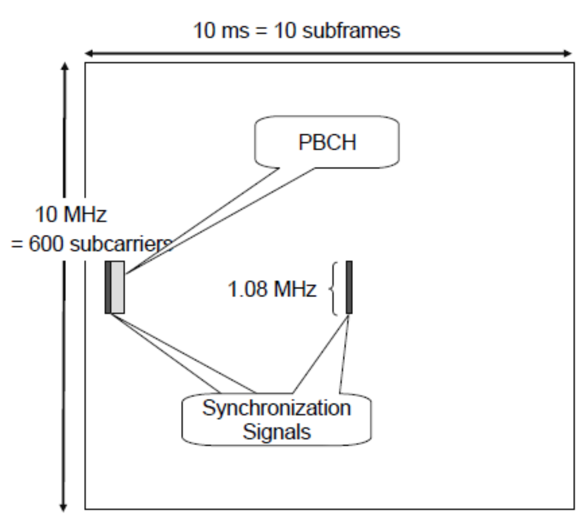


Figure 11. PBCH location at the center frequency

Physical channel	Modulation scheme
PBCH	QPSK

Table 10. PBCH modulation scheme

Physical Multicast Channel (PMCH)

The Physical Multicast Channel carries the multicast channel (MCH) which is characterized by:

- requirement to be broadcast in the entire coverage area of the cell
- support for MBSFN combining of MBMS transmission on multiple cells
- support for semi-static resource allocation (for example, with a time frame of a long cyclic prefix).

Physical channel	Modulation schemes
PMCH	QPSK, 16QAM, 64QAM

Table 11. PMCH modulation schemes

Reference Signal

The cell site (eNB) determines the downlink transmission energy per resource element. User equipment (UE) may assume downlink cell-specific reference signal (RS) energy per resource element (EPRE) to be constant across the downlink system bandwidth and constant across all subframes until different cell-specific reference signal (RS) power information is received.

The downlink RS EPRE can be derived from the downlink RS transmission power given by the RS signal power provided by higher layers. The downlink RS transmit power is defined as the linear average over the power contributions (in [W]) of all resource elements that carry cell-specific RSs within the operating system bandwidth.

Three types of downlink RSs are defined:

- cell-specific reference signals, associated with non multimedia broadcast multicast service single frequency network (MBSFN) transmission
- MBSFN reference signals, associated with MBSFN transmission
- UE-specific reference signals.

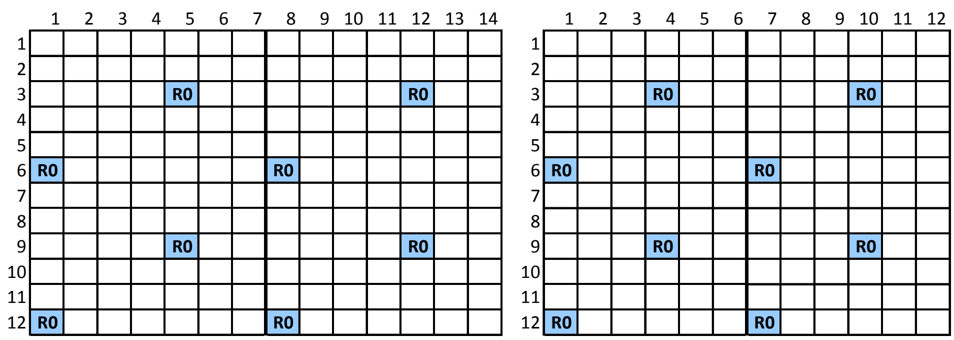
The downlink RSs consist of known reference symbols inserted in the first and third last OFDM symbol of each slot. There is one RS transmitted per downlink antenna port. The number of downlink antenna ports equals 1, 2, or 4.

The two-dimensional RS sequence is generated as the symbol-by-symbol product of a two-dimensional orthogonal sequence and a two-dimensional pseudo-random sequence. There are three different two-dimensional orthogonal sequences and 170 different two-dimensional pseudo-random sequences. Each cell identity corresponds to a unique combination of one orthogonal sequence and one pseudo-random sequence, thus allowing for 504 unique cell identities and 168 cell identity groups with three cell identities in each group.

Cell Specific Reference Signals

Cell-specific reference signals shall be transmitted in all downlink subframes in a cell supporting non-MBSFN transmission. In case the subframe is used for transmission with MBSFN, only the first two OFDM symbols in a subframe can be used for transmission of cell-specific reference symbols. (Ref 1)

Cell-specific reference signals are transmitted on one or several of antenna ports 0 to 3. (Ref 1)



(a) Normal cyclic prefix (b) Extended cyclic prefix

Figure 12. Mapping of downlink RSs for SISO (Ref. 1)

MBSFN Reference Signals

MBSFN reference signals shall only be transmitted in subframes allocated for MBSFN transmission. MBSFN reference signals are transmitted on antenna port 4.

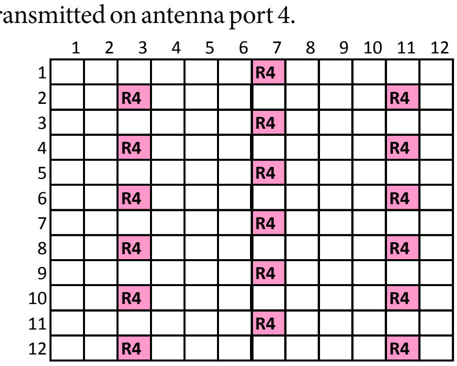
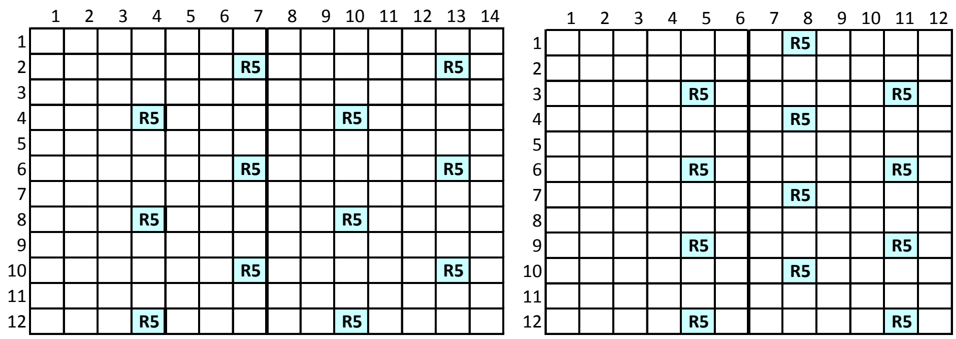


Figure 13. Mapping of MBSFN RSs (extended cyclic prefix Δf = 15 KHz) (Ref. 1)

UE Specified Reference Signals

UE-specific reference signals are supported for single-antenna-port transmission of downlink shared channel (PDSCH) and are transmitted on antenna port 5. The UE is informed by higher layers whether the UE-specific reference signal is present and is a valid reference for PDSCH demodulation. UE-specific reference signals are transmitted only on the resource blocks upon which the corresponding PDSCH is mapped.



(a) Normal cyclic prefix (b) Extended cyclic prefix

Figure 14. Mapping of UE-specific RSs (Ref 1)

Synchronization Signals

Similar to WCDMA, which has 512 orthogonal primary scrambling codes or identifiers, LTE has 504 unique cell identifiers. The primary synchronization signal (P-SS) and secondary synchronization signal (S-SS) jointly define 504 unique physical-layer cell identities (PCIs).

The PCIs are grouped into 168 PCI groups each with 3 PCIs (3 x 168 = 504). P-SS and S-SS occupy 1.08 MHz bandwidth in frequency domain, equal to six resource blocks, and are located on the last two REs in the first and 11th timeslot.

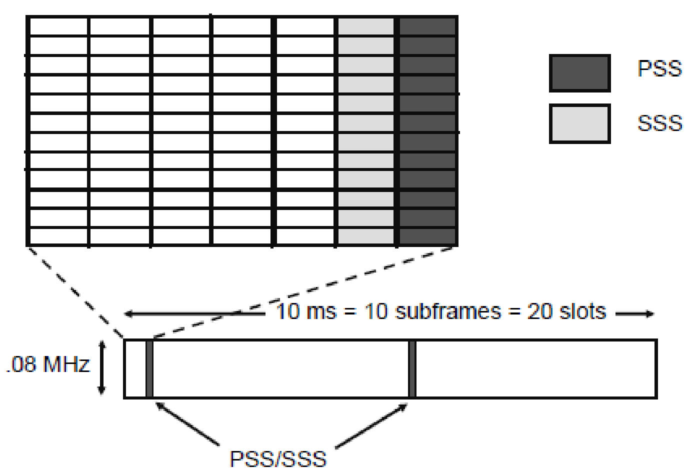


Figure 15. Synchronization signals in the frame

LTE Downlink Map

LTE downlink resources can be dynamically allocated user-by-user depending on the data rate provided to the specific user. Therefore, it is more intuitive to display the downlink frame with a two-dimensional diagram. Figure 16 shows the LTE RE allocation profile of a 10 ms LTE downlink frame where the channel bandwidth is 10 MHz and the subcarrier interval is 15 kHz.

As shown in the diagram, the primary synchronization channel (P-SCH) carrying P-SS and the secondary synchronization channel (S-SCH) carrying S-SS are placed in the latter symbols of TS0 and TS10 occupying 1.08 MHz bandwidth at the center of the transmission band.

User equipment (UE) can get synchronized with the base station by monitoring the downlink signal during 5 ms for the 1.08 MHz bandwidth.

The broadcast channel (PBCH) is located at the beginning of T_S1 or the second timeslot on the first subframe and also occupies 1.08 MHz bandwidth. This scheme enables the UE to get information about the base station.

The downlink control channels (PDCCH) are located at the beginning of every subframe and the information about how many RE are assigned for PDCCH in the downlink frame are delivered by the control format indicator channel (PCFICH).

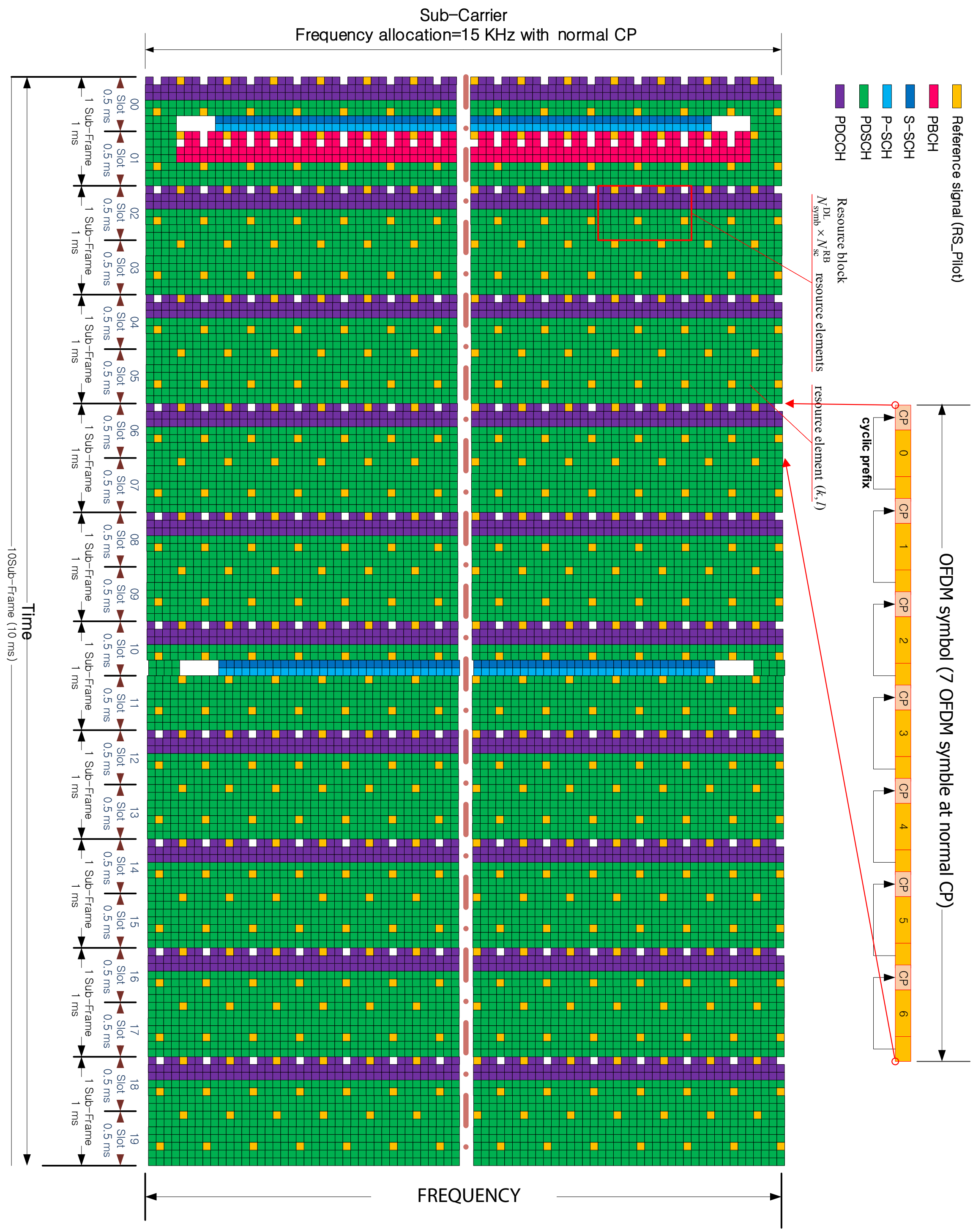


Figure 16. Downlink map of 10 ms LTE frame (Δf =15 KHz, normal CP)

LTE PHY Measurement

The 3GPP requirements for LTE transmitters can be grouped in the following three categories:

- output power control capability of base station. OFDMA allows dynamic resource allocation to the system. Thus, the eNB can handle a wide dynamic range of RB configurations while maintaining high quality of service (QoS).
- transmitted signal modulation quality, also known as error vector magnitude (EVM) requirements. These requirements will determine the in-channel performance for the transmission portion of the downlink.
- unwanted emissions, for inside and outside the operating band. The corresponding requirements will ensure the RF compatibility of the LTE downlink with systems operating in adjacent frequency bands.

To ensure the performance of LTE transmitters based on the above three categories, 3GPP recommends performing the following tests for LTE-FDD base stations:

- base-station output power
- output power dynamic
- frequency error
- modulation quality metric using error vector magnitude (EVM)
- MIMO time alignment between transmitter's branches
- downlink reference signal power
- occupied bandwidth
- adjacent channel leakage power ratio (ACLR)
- operating band unwanted emissions
- transmitter's spurious emissions.

Base Station Analyzer

The Base Station Analyzer includes all measurements required to properly characterize the cell site infrastructure and verify the overall base station performance. The key measurement functions supported by the Base Station Analyzer are the following:

- spectrum analyzer
- cable and antenna analyzer
- power meter
- interference analysis
- channel scanner
- backhaul analysis (E1, T1, Ethernet)
- Signal analysis for the following technologies:
  - cdmaOne/CDMA2000
  - EV-DO
  - GSM/ GPRS/ EDGE
  - WCDMA/HSDPA
  - TD-SCDMA
  - Mobile WiMAX
  - LTE-FDD and LTE-TDD.

The Base Station Analyzer covers all the above measurement parameters except band emissions due to its extended frequency requirement. The Base Station Analyzer measurement summary is as follows:

- channel power
- occupied bandwidth
- spurious emission mask (SEM)
- adjacent channel leakage power ratio (ACLR)
- signal quality analysis (demodulator)
  - data channel summary
  - control channel summary
  - subframe summary
  - frame summary
  - power vs. time (P vs. T)
  - complementary cumulative distribution function (CCDF)
  - MIMO time alignment
- Over the air analysis
  - ID scanner
  - downlink datagram
  - control channels

The following table shows the relationship between the Base Station Analyzer tests and 3GPP's requirements.

3GPP requirements		Base Station Analyzer tests	Remarks
Base station output power		channel power	Integrated power of transmitted signal on frequency domain.
		P vs. T	transmitted frame power level on time domain.
Output power dynamic		CCDF	statistical distribution of OFDMA symbol power.
Modulation accuracy	frequency error	control channel summary	frequency error of subcarriers.
		subframe summary	
		frame summary	
	error vector magnitude	data channel summary	modulation quality of all resource blocks of a defined subframe.
		control channel summary	modulation quality of all control channels in a defined subframe.
		subframe summary	modulation quality of all channels in a defined subframe.
		frame summary	modulation quality of all channel in a frame.
	time alignment	time alignment error (MIMO)	time difference between antenna 0 (RS-0) and antenna 1 (RS-1).
	DL RS power	control channel summary	power level of all control channels in a defined subframe.
		subframe summary	power level of all channels contained on a defined subframe
		frame summary	power level of all channels contained on a frame.
Unwanted emissions	occupied bandwidth	occupied BW	occupied bandwidth for 99% of transmitted power
	adjacent leakage power ratio	ACLR	power ratio between carrier and inter-modulated signal power.
	operating band unwanted emission	SEM	unwanted emission at the out of channel.
	out-of-band unwanted emissions	spurious emission	unwanted emissions measured out of band.

Table 12. Base Station Analyzer tests and 3GPP requirements

LTE Test Model

The transmitter's physical channels set-up tests shall be according to one of the E-UTRA test models (E-TM) as described below. A reference to the applicable test model is made in each test.

The following general parameters are used by all E-UTRA test models:

- the test models are defined for a single antenna port (using p = 0); one code word (q = 0), one layer, and pre-coding is not used
- duration is 10 subframes (10 ms)

- normal cyclic prefix
- virtual localized resource blocks (mapped directly to physical resource blocks), and no intra-subframe hopping for PDSCH
- UE-specific reference signals are not used.

The physical channels power setting is defined by the physical channel of energy per resource element (EPRE) relative to the reference signal. The relative accuracy of the physical channel EPRE as referred to the EPRE of the RS shall have a tolerance of ±0.5 dB.

The following table shows the applicable E-UTRA test models for each measurement item.

Measurement item		**E-TM**	**E-TM 1.1**	**E-TM 1.2**	**E-TM 2**	**E-TM 3.1**	**E-TM 3.2 3.3**
BS output power		■					
Total power dynamic range					■ (*note 1)	■ (*note 2)	
Occupied Bandwidth		■					
ACLR		■	■				
Operating band unwanted emission		■	■				
Transmitter intermodulation		■					
RS absolute accuracy		■					
EVM	QPSK						■
	16 QAM					■	
	64 QAM (single PRB)				■ (*note 1)	■ (*note 2)	
Frequency error					■ (*note 1)	■ (*note 2)	■

*note 1: at minimum power condition

*note 2: at maximum power condition

Table 13. E-UTRA test model applicability map

Base Station Analyzer Measurement Setup

The following parameters should be properly set on the Base Station Analyzer to test and measure the LTE transmitter:

- Trigger—four types of trigger modes are available
  - Internal—sets the trigger to internal reference
  - External—sets the trigger to external reference
  - GPS—sets the trigger to built-in GPS receiver
  - Free—sets the trigger mode to free run
- Subframe No.—allows the selection of the downlink subframe number to analyze

- PHICH Ng—sets the group number (Ng) of the hybrid ARQ indicator channel (PHICH) transmitted over one subframe period. The PHICH group number is equal for all subframes where Ng ∈ {1/6, 1/2, 1, 2}. Since this parameter is defined on higher layers, it should be properly set. The relation between PHICH group and Ng for 10 MHz channel bandwidth is described in the following table.

Cyclic Prefix	Ng	PHICH group
Normal	1/6	1
	1/2	4
	1	7
	2	13
Extended	1/6	4
	1/2	8
	1	14
	2	26

Table 14. PHICH group numbers

- # of CFI—sets the number of OFDMA symbols set in a subframe where a symbol set refers to all subcarriers that belong to the same symbol
- Cyclic Prefix—sets the type of cyclic prefix as normal or extended
- Cell ID—sets the identifier of the cell site under test. The manual setting lowers the cell search time and improves the synchronization time with the LTE signal. The automatic (Auto) setting allows the instrument to obtain the cell-ID from the received signal.
- PDSCH Mod Type—sets the modulation scheme of the downlink shared channel (PDSCH).

Power Measurement

There are two required measurements defined by 3GPP: base station output power and total power dynamic range. However, they are considered equivalent since it is required to measure the output power of the base station under varying output power.

Power measurements can be done in the following tests depending on the base station power performance characteristic.

- Channel power
- Power vs. time (P vs. T)
- Complementary cumulative distribution function (CCDF).

Channel Power

Channel power measures the base station's transmitting power in the frequency domain. The Base Station Analyzer measures the signal power over frequency, showing the signal spectrum and displaying the average power value.

The following figure shows the channel power measurement result of an LTE DL signal where the transmission bandwidth is 9 MHz corresponding to 10 MHz channel bandwidth. The highlighted zone on the trace indicates the transmission bandwidth.

Figure 17. Channel power measurement (E-TM1.1)

Under the trace, the resulting channel power is displayed with the integral bandwidth. Spectral density shows the power contained in 1 Hz and is obtained by dividing the channel power by the integral bandwidth.

In the Channel Power function, the following Base Station Analyzer parameters are set as default values.

- RBW—100 kHz
- VBW—100 Hz
- Span—30 MHz
- Attenuation—Auto
- Reference Level—Auto.

Power vs. Time

The Power vs. Time (P vs. T) measurement provides information related to the trend of the transmitted power over one frame period. In P vs. T mode, the test triggers with timing reference and samples power contained in the 9 MHz bandwidth over 10 ms.

Additional information is presented by the Base Station Analyzer such as cell identity, I-Q offset, time offset, subframe, and frame power.

Figure 18. Power vs. Time measurement for TM1.1

- Frame Power—the average power of a full LTE frame
- Subframe No—the number of the specified subframe
- Cell ID—the cell identity
- I-Q Origin offset—shows the relative DC offset of I and Q symbols in dB scale on the reference of average voltage of received symbols
- Time Offset—shows the time difference between timing reference and frame sync
- Subframe Power—the averaged power of the specified subframe
- First Slot Power—the averaged power of the first timeslot in the specified subframe
- Second Slot Power—the averaged power of the second timeslot in the specified subframe.

In the P vs. T function, the following parameters are set as default values on the Base Station Analyzer.

- RBW—100 kHz
- Attenuation—Auto.

The following Base Station Analyzer settings may affect the measurement accuracy, thus some consideration is recommended.

- Freq. Offset—may affect the overall measurement accuracy
- Cyclic Prefix—may affect the subframe and slot power accuracy
- RF in Loss—may affect the overall power measurement accuracy.

Complementary Cumulative Distribution Function (CCDF)

The complementary cumulative distribution function (CCDF) measures the power distribution of the transmitted signal. CCDF is not a mandatory measurement for installation, but it is a useful parameter to optimize the base station output power covering a wide area without degrading QoS during operation.

In addition to its inherent high peak to average power ratio (PAR) characteristic of OFDMA, using 16 QAM or 64 QAM modulation in downlink shared channels (PDSCH) requires an amplifier with wide dynamic range in eNB. A high performance amplifier ensures QoS, but it incurs installation, operation, and maintenance costs. Therefore, it is important to measure CCDF and adjust the eNB output power to ensure QoS.

The following figure shows the CCDF measurement result of the Base Station Analyzer for E-UTRA TM1.1. A Gaussian distribution curve is displayed as a reference line.

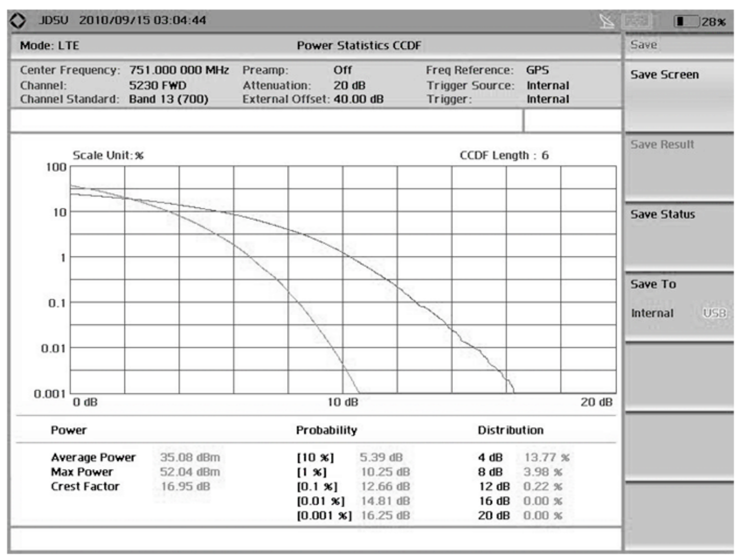


Figure 19. CCDF measurement for TM1.1

The CCDF measurement of the Base Station Analyzer shows the following information:

- Avg. Power—the average power of specified symbol measured over the signal bandwidth
- Max Power—the highest power among the measured data
- Crest factor—obtained by subtracting Avg. Power from Max Power
- Probability—refers to the power data located within the pre-positioning percentage from the average power
- Distribution—refers to the percentage of data located beyond prepositioning power difference form the average power. For example, if 4 dB is 9.36% then it means 90.64% of measured power data are lower than 4 dB of the average power.

In the CCDF function, the following parameters are set as default values on the Base Station Analyzer:

- RBW—100 kHz
- Attenuation—Auto.

The following Base Station Analyzer settings may affect the measurement accuracy and some consideration is recommended.

- Freq. Offset—affects the overall measurement accuracy
- RF In Loss—affects the accuracy of Avg. Power.

Modulation Accuracy Measurement

The purpose of base-station demodulation performance requirements is to estimate how the network is performing and to verify possible eNB impairments that can cause network degradation. eNB impairments include RF and baseband impairments, receiver EVM, time and frequency tracking, and frequency estimation, among others.

3GPP recommends modulation-specific error vector magnitude (EVM) requirements to ensure high-quality signals of the eNB. Typical impairments of the transmitted signal modulation accuracy are analog RF distortions (frequency offset, local oscillator phase noise, amplitude/phase ripple from analog filters) as well as distortions created within the digital domain such as inter-symbol interference from digital filters used for symbol shaping, finite word length effects, and, most important for conditions near maximum transmit power, the clipping noise from peak-to-average ratio reduction.

The EVM requirement ensures that the downlink throughput due to the non-ideal waveform in the eNB is only marginally reduced, typically by 5% assuming an ideal reception in the UE. The required EVM must be fulfilled for all transmission configurations and across the entire dynamic range of power levels used by the eNB.

It is known that the following factors affect the modulation accuracy of transmitters:

- carrier rejection—as the measurement is made after ZF-equalization, the Base Station Analyzer partially removes this contribution. LTE standardization has set a separate specification for carrier rejection to ensure that the carrier level stays within reasonable limits for the ZF algorithm. At low output power, a small DC offset in the TX chain generates high carrier leakage to a point where the transmission power control (TPC) accuracy may not be within specifications. For this reason, carrier-leakage compensation is implemented in RF transmitters and this technique generally achieves 40 dB of carrier rejection throughout the TPC range, making this contribution negligible in the EVM budget.
- even-order distortion—even order non-linearity contributes mainly to adjacent channel leakage ratio (ACLR) as the main effect is to enlarge the transmitted spectrum. As ACLR requirements are 33 dB and 43 dB in adjacent and alternate channels, these contributions are usually negligible in terms of EVM.
- local oscillator phase noise—the induced jitter generates phase error in the modulation constellation, thus contributing to EVM
- power-amplifier distortion—amplifier distortion has a contribution to EVM and also generates asymmetrical spectral energy in the adjacent channels
- image—the signal image generated by the quadrature imperfections in the up-mixing process can be considered as band noise contributing to the TX signal-to-noise ratio (SNR)

- group-delay distortion—LTE has an I/Q BW of 5 MHz for 30 MHz duplex distance or 10 MHz for 80 MHz duplex distance. Significant broadband filtering is required to ensure that I/Q noise at the duplex frequency offset is low.

Overall, the LTE EVM specification requires special attention to the higher bandwidth and smaller duplex distances. For the same reasons, the TX out-of-band noise is more difficult to achieve in LTE.

The Base Station Analyzer satisfies the requirement of 3GPP for modulation accuracy measurement for LTE signals. In addition to this, it provides additional features for more in-depth analysis such as:

- Frame Summary
- Subframe Summary
- Control Channel Summary
- Data Channel Summary.

Frame Summary

3GPP recommends that EVM should be taken from the shared channel (PDSCH) in a frame excluding control channels and reference signals. In addition to this, with this function, the Base Station Analyzer shows the status of all data channels, control channels, and reference signals including EVM, power, frequency offset, and I-Q origin offset.

The following figure shows the Base Station Analyzer Frame Summary measurement screen for E-UTRA TM3.2 where the channel bandwidth is 10 MHz.

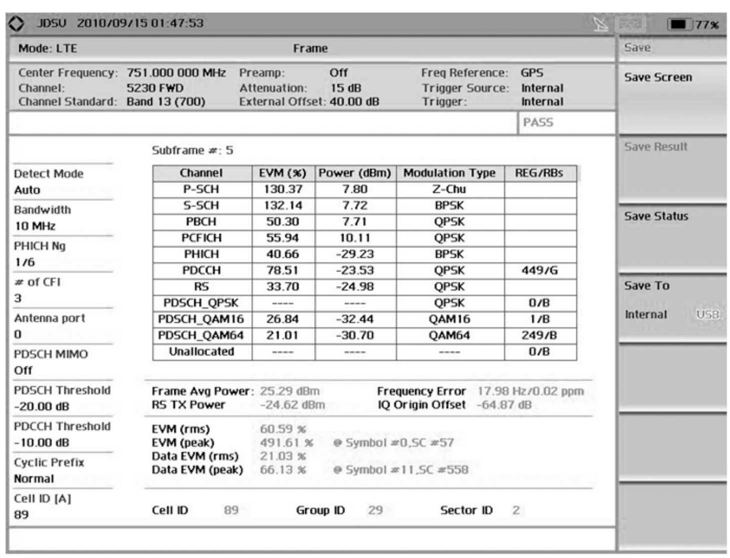


Figure 20. Frame Summary measurement for 10 MHz LTE DL signal (E-UTRA TM3.2)

The Base Station Analyzer Frame Summary measurement consists of three sections: the upper section for error summary, the middle section for channel status, and the lower section for power metrics.

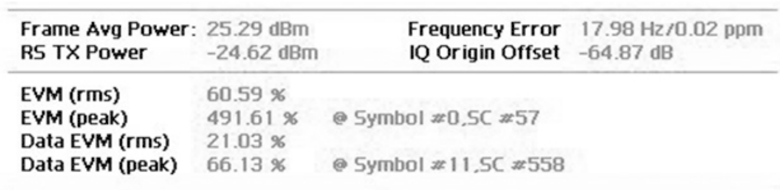


Figure 21. Error summary in Frame Summary screen

The above figure shows the error summary where each parameter is defined as follows:

- EVM RMS—the averaged EVM for all resource elements (RE) allocated including control, data channels, and reference signal
- EVM Peak—the EVM for a specific RE which has the worst EVM. It is also displayed the location of the worst RE.
- Data EVM RMS—the averaged EVM for all RE allocated for shared channels (PDSCH). It stands for the EVM of eNB as specified by 3GPP TS 36.104. The EVM for different modulation schemes on PDSCH shall be less than the limits shown in the following table.

Modulation scheme for PDSCH	Required EVM [%]
QPSK	17.5%
16 QAM	12.5%
64 QAM	8%

Table 15,ljklll.. EVM requirement (Ref. 3)

- 3GPP requires that data EVM measurements should be performed with TM2, TM3.1, TM3.2 and TM3.3 to ensure the eNB performance for variable channel and power configurations.
- Data EVM Peak—the EVM for a specific RE allocated for PDSCH with the highest EVM. The RE location is also displayed.
- Frequency Offset—the difference between the frequency of the subcarrier and the user defined center frequency. 3GPP recommends that the modulated carrier frequency of the eNB shall be accurate to within ±0.05 ppm observed over a period of one subframe (1 ms).
- IQ Origin Offset—the relative DC offset of I and Q symbols in dB based on received symbols average voltage
- Cell ID—the eNB identity number
- Group ID—the eNB identity group number where there are 168 cell-identity groups and each group consists of three identity numbers
- Sector ID—the cell-identity number within the cell-identity group (0, 1 or 2).

It is useful to consider the relationship between the measurement result and the channel configuration of E-TM because it is important to verify the eNB performance with the E-TMs defined by 3GPP. The following table shows the channel configuration of E-TM3.2 for various channel bandwidths.

Parameter	**1.4 MHz**	**3 MHz**	**5 MHz**	**10 MHz**	**15 MHz**	**20 MHz**
Reference, Synchronization Signals						
RS boosting, $P_B = E_B/E_A$	1	1	1	1	1	1
Synchronisation signal EPRE/E_{RS} [dB] 0.000	1.573	2.426	2.426	3.005	2.426	
Reserved EPRE/E_{RS} [dB]	-inf	-inf	-inf	-inf	-inf	-inf
PBCH						
PBCH EPRE/E_{RS} [dB]	0.000	1.573	2.426	2.426	3.005	2.426
Reserved EPRE/E_{RS} [dB]	-inf	-inf	-inf	-inf	-inf	-inf
PCFICH						
# of symbols used for control channels	2	1	1	1	1	1
PCFICH EPRE/E_{RS} [dB]	3.222	0	0	0	0	0
PHICH						
# of PHICH groups	1	1	1	2	2	3
# of PHICH per group	2	2	2	2	2	2
PHICH BPSK symbol power/E_{RS} [dB]	- -3.010	- -3.010	- -3.010	- -3.010	- -3.010	- -3.010
PHICH group EPRE/E_{RS} [dB]	0	0	0	0	0	0
PDCCH						
# of available REGs	23	23	43	90	140	187
# of PDCCH	2	2	2	5	7	10
# of CCEs per PDCCH	1	1	2	2	2	2
# of REGs per CCE	9	9	9	9	9	9
# of REGs allocated to PDCCH	18	18	36	90	126	180
# of <NIL> REGs added for padding	5	5	7	0	14	7
PDCCH REG EPRE/E_{RS} [dB]	0.792	2.290	1.880	1.065	1.488	1.195
<NIL> REG EPRE/E_{RS} [dB]	-inf	-inf	-inf	-inf	-inf	-inf
PDSCH						
# of 16QAM PDSCH PRBs within a slot for which EVM is measured	4	7	15	30	50	60
PRB PA = E_A/E_{RS} [dB]	-3 (*)	-3	-3	-3	-3	-3
# of QPSK PDSCH PRBs within a slot where EVM is not measured (used for power balancing only)	2	8	10	20	25	40
PRB $P_A = E_A/E_{RS}$ [dB]	3.005 (*)	1.573	2.426	2.426	3.005	2.426

E_A: EPRE (energy per resource element) of PDSCH REs (resource elements) type A, for example, REs in OFDM symbols that do not include reference symbols

E_B: EPRE of PDSCH REs type B, i.e. REs in OFDM symbols that include reference symbols

E_{RS}: EPRE of reference symbols REs.

Table 16. Channel configuration of E-TM3.2

In the case of LTE signals of 10 MHz, it is advisable to compare the value of each parameter with the resulting value displayed in the Base Station Analyzer Frame Summary measurement. The following figure shows the channel status of the Frame Summary measurement.

Channel	EVM (%)	Power (dBm)	Modulation Type	REG/RBs
P-SCH	130.37	7.80	Z-Chu	
S-SCH	132.14	7.72	BPSK	
PBCH	50.30	7.71	QPSK	
PCFICH	55.94	10.11	QPSK	
PHICH	40.66	-29.23	BPSK	
PDCCH	78.51	-23.53	QPSK	449/G
RS	33.70	-24.98	QPSK	
PDSCH_QPSK	----	----	QPSK	0/B
PDSCH_QAM16	26.84	-32.44	QAM16	1/B
PDSCH_QAM64	21.01	-30.70	QAM64	249/B
Unallocated	----	----	----	0/B

Figure 22. Channel status in the Frame Summary measurement

The channel status parameters in the Frame Summary Measurement are defined as follows:

- EVM —the error vector magnitude of all channels and reference signals averaged over a period of one frame
- Pwr[dB]—the relative power of each channel on the reference of energy per resource element EPRE of PDSCH. From the values shown in table 13:
  - RS boosting is defined as $P_B = E_B/E_A = 1$, thus the RS power should be 0 dB
  - Sync Signal is defined as synchronization signal EPRE/ERS [dB] = 2.426, thus the P-SS and S-SS power should be 2.426 dB
  - PBCH EPRE ERS [dB] = 2.426, thus the PBCH power should be 2.426 dB
  - PCFICH EPRE ERS [dB] = 0, thus the PCFICH power should be 0 dB
  - PHICH group EPRE ERS [dB] = 0, thus the PHICH power should be 0 dB
  - PDCCH REG EPRE ERS [dB] = 1.065, thus the PDCCH power should be 1.065 dB
  - For 16 QAM-modulated PDSCH, PRB $P_A = E_A/E_{RS}$ [dB] = -3, thus the PDSCH power should be 3 dB lower than RS
  - For QPSK-modulated PDSCH, PRB $P_A = E_A/E_{RS}$ [dB] = 2.426, thus the PDSCH power should be 2.426 dB higher than RS.
  - Mode Type—the modulation scheme of each channel
  - REG/RBs—the number of resource element groups in resource blocks allocated for the specific channel or signal.

In the Summary function, the following JD7105A parameters are set as default values on the Base Station Analyzer.

- RBW—100 kHz
- Attenuation—Auto.

The following Base Station Analyzer settings may affect the measurement accuracy, thus some consideration is recommended:

- Freq. Offset—may affect the overall measurement accuracy
- Cyclic Prefix—setting may affect the subframe and slot power accuracy
- RF In Loss—may affect the overall power measurement accuracy
- # of CFI—may affect the Channel Summary measurement result.

Subframe Summary

The Subframe Summary function analyzes the LTE frame in detail. Since the resource scheduling is made by subframe, the Subframe Summary measurement shows which subframes are not working properly. In addition, the Subframe Summary provides modulation errors, power and resource allocation status of all channels contained in a specific subframe.

The 3GPP recommends that the frequency error measurement should be done in each subframe.

Note: Some control channels were not transmitted in the selected subframe thus the measurement result may remain blank.

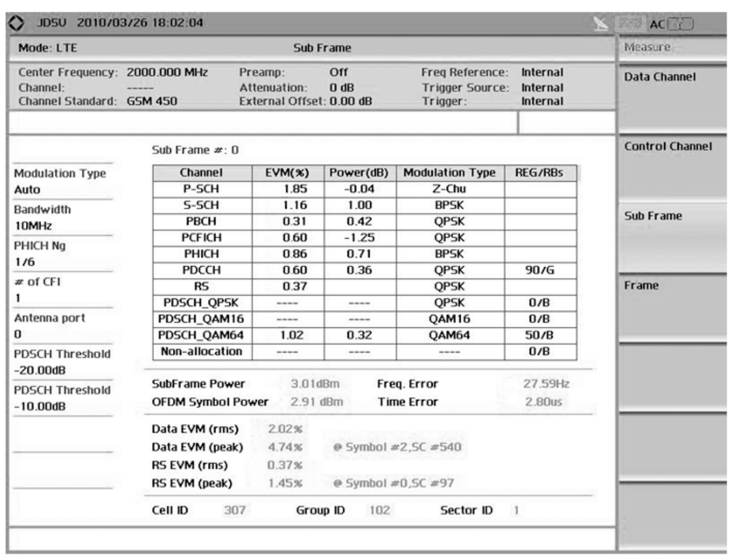


Figure 23. Subframe Summary measurement for E-TM3.2

The above figure shows the measurement result of the first subframe and, similar to Frame Summary, Subframe Summary consists of three sections: error summary, channel status, and power metrics.

The Subframe Summary measurement parameters are defined as follows:

- EVM RMS—the averaged EVM for all resource elements (RE) allocated including control, data channels, and reference signal
- EVM Peak—the EVM for a specific RE which has the worst EVM. It is also displayed the location of the worst RE.
- Data EVM RMS—the averaged EVM for all RE in the subframe allocated for PDSCH
- Data EVM Peak—the EVM for a specific RE in the subframe allocated for PDSCH with the highest EVM. The RE location is also displayed.
- Frequency Offset—the difference between the frequency of the subcarrier and the user-defined center frequency. 3GPP recommends the frequency error should be maintained within the following limits while the Base Station Analyzer and the eNB under test are synchronized with the same reference frequency:

$$\textit{frequency error} \leq \textit{within} \pm (0.05\,ppm + 12Hz)$$

- IQ Origin Offset—the relative offset of I and Q symbol in dB based on received symbols average voltage
- Cell ID—the eNB identity number
- Group ID—the eNB identity group number where there are 168 cell-identity groups and each group consists of three identity numbers
- Sector ID—the cell-identity number within the Cell-Identity group (0, 1 or 2).

The following figure shows the channels and signals summary for the given subframe:

Channel	EVM(%)	Power(dB)	Modulation Type	REG/RBs
P-SCH	1.85	-0.04	Z-Chu	
S-SCH	1.16	1.00	BPSK	
PBCH	0.31	0.42	QPSK	
PCFICH	0.60	-1.25	QPSK	
PHICH	0.86	0.71	BPSK	
PDCCH	0.60	0.36	QPSK	90/G
RS	0.37		QPSK	
PDSCH_QPSK	----	----	QPSK	0/B
PDSCH_QAM16	----	----	QAM16	0/B
PDSCH_QAM64	1.02	0.32	QAM64	50/B
Non-allocation	----	----	----	0/B

Figure 24. Physical channel summary on Subframe Summary (E-TM3.2)

In the Subframe Summary function, the following parameters are set as default values on the Base Station Analyzer.

- RBW—100 kHz
- Attenuation—Auto.

The following settings may affect the measurement accuracy, thus some consideration is recommended.

- Freq. Offset—may affect the overall measurement accuracy
- Cyclic Prefix—setting may affect the subframe and slot power accuracy
- RF In Loss—may affect the overall power measurement accuracy
- # of CFI—may affect the Channel Summary measurement result.

Data Channel Summary

The Data Channel Summary function shows the power of each resource block (RB) and modulation quality of each RB with its corresponding constellation diagram. Since the control channel (PDCCH) is transmitted at the beginning of every subframe and the number of RE sets for control channel is defined by the control format indicator (PCFICH), the Base Station Analyzer excludes the RE sets which are allocated for PDCCH transmission on the reference of # of CFI setting.

The following figure shows the Base Station Analyzer Data Channel Summary measurement screen. It consists of two sections: the upper section is the resource block power diagram and the lower section is the constellation diagram.

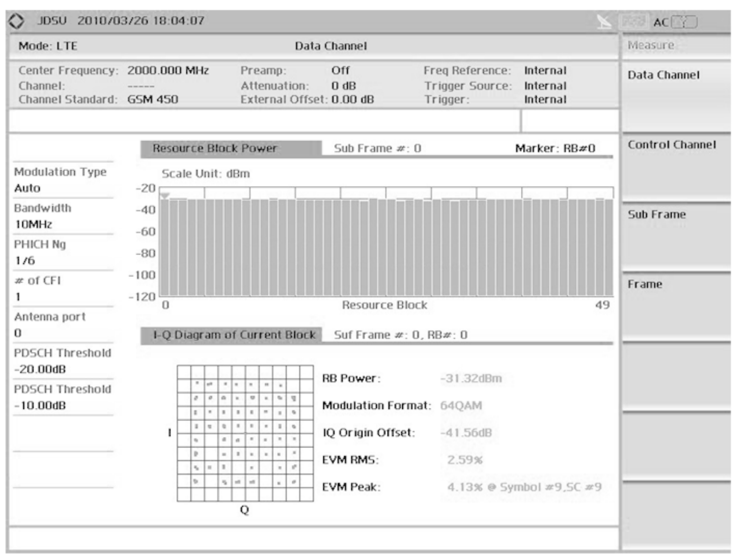


Figure 25. Data Channel Summary (E-TM3.2)

In the resource block power diagram, the power of each resource block is displayed as a color code where the color index is located at the right side of the diagram. The following figure shows a resource block power diagram:

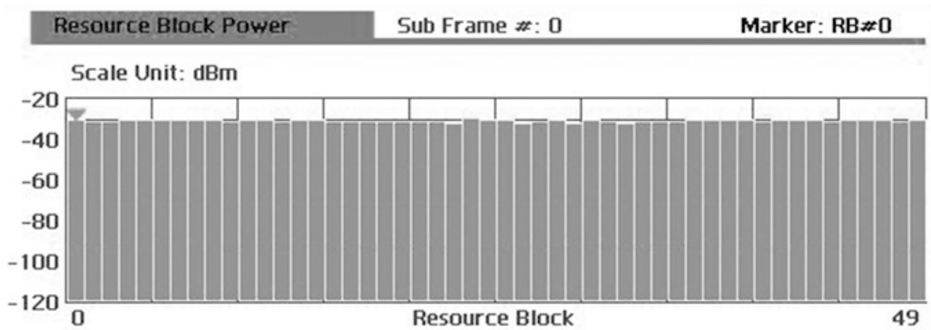


Figure 26. Resource block power diagram in Subframe Summary measurement

The Resource Block is selectable on the Base Station Analyzer by pressing [Marker]-[Knob/Arrow] key. For LTE at 10 MHz, the maximum number of resource blocks is 50. The reference level and minimum level of the power index is linked with the amplitude setting.

The I-Q diagram (Constellation) plots the symbol data of a selected resource block and shows the modulation error of that symbol. Since the EVM calculation is done for each RE, the location of worst RE is displayed with the EVM peak.

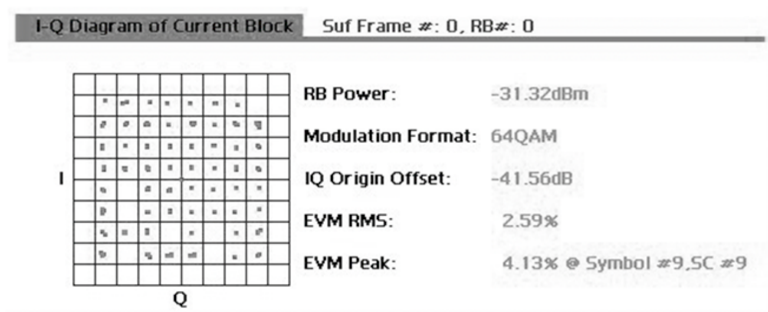


Figure 27. I-Q diagram in the Subframe Summary measurement

The I-Q diagram parameters in the Subframe Summary measurement are defined as follows:

- RB Power—the averaged power of all REs in the selected RB over one subframe period. Since it only deals with PDSCH, the RE for PDCCH is not included. In case of a 10 MHz LTE frame, there are 50 RBs in the frequency domain thus if all RB have the same power then the RB power is about 10log(1/50)= -17 dB lower than the subframe power.
- Modulation Format—the modulation scheme being used for the PDSCH in the resource block
- I-Q Origin Offset—the degree of deviation of the hypothetical center of detected symbol from the center of I-Q diagram
- EVM RMS—the root-mean-square of individual EVM of each RE in the resource block
- EVM Peak—the EVM value of the RE which has the worst individual EVM. It is also displayed the location of the worst RE.

In the Data Channel Summary function, the following parameters are set as default values on the Base Station Analyzer.

- RBW—100 kHz
- Attenuation—Auto.

The following JD7105A settings may affect the measurement accuracy, thus some consideration is recommended.

- Freq. Offset—may affect the overall measurement accuracy
- Cyclic Prefix—setting may affect the subframe and slot power accuracy
- RF In Loss—may affect the overall power measurement accuracy.

Control Channel Summary

The Control Channel Summary function shows the status of control channels and reference signals for a defined subframe including the corresponding constellation diagram of a selected channel.

The Channel Summary section shows the configuration status of each channel together with the base station identifier and control format indicator (CFI) data.

The I-Q Diagram section shows the power and modulation format of the highlighted channel.

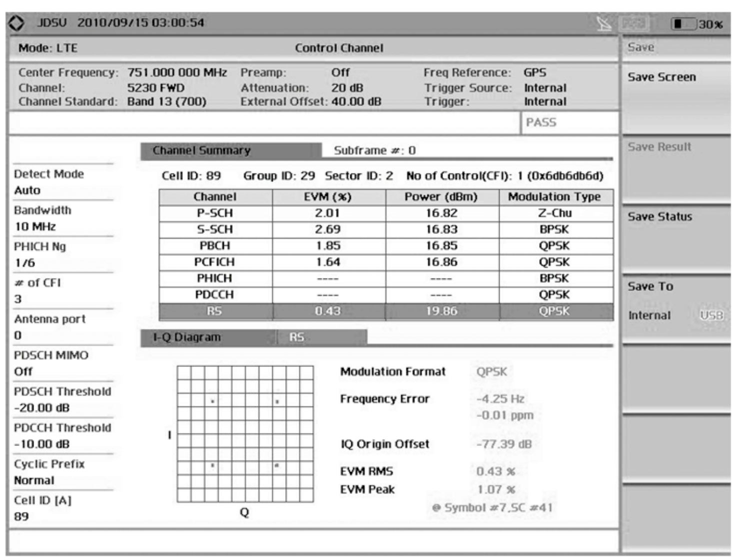


Figure 28. Control Channel Summary measurements

In the Channel Summary section, channels can be selected by pressing the [Marker]-[Knob/Arrow] key. The constellation diagram of the selected channel is displayed in the I-Q diagram section with the modulation quality parameters.

The power of each channel is defined as follows:

- P-SS power [dB] = (primary synchronization signal EPRE)/E_{RS} [dB]
- S-SS power [dB] = (secondary synchronization signal EPRE)/E_{RS} [dB]
- PBCH power [dB] = PBCH EPRE/E_{RS} [dB]
- PCFICH power [dB] = PCFICH EPRE/E_{RS} [dB]
- PHICH power [dB] = PHICH Group EPRE/E_{RS} [dB]
- PDCCH power [dB] = PDCCH REG EPRE/E_{RS} [dB]

CFI shows the RE set for the control channel (PDCCH). The control format indicator channel (PCFICH) contains the 32bit data. The CFI coded data is described in the following table:

CFI	CFI codeword < b0, b1, …, b31 >	HEX
1	0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1	6db6db6d
2	1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0	B6db6db6
3	1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1,0,1,1	Db6db6db
4 (Reserved)	0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0	

Table 17. CFI codes

In the Control Channel Summary function, the following parameters are set as default values on the Base Station Analyzer:

- RBW—100 kHz
- Attenuation—Auto.

The following Base Station Analyzer settings may affect the measurement accuracy, thus some consideration is recommended.

- Freq. Offset—may affect the overall measurement accuracy
- Cyclic Prefix—setting may affect the subframe and slot power accuracy
- # of CFI—may affect the Channel Summary measurement result.

MIMO Time Alignment

Multiple input multiple output (MIMO) techniques are used for spatial multiplexing or beamforming performance improvement since the transmitted signal will take different physical paths. There are three main applications:

- Path diversity – where one radiated path may be subject to fading loss and another may not
- Beam steering – controlling the phase relationship of the electrical signal radiated at the antennas to physically steer transmitted energy
- Path difference – separating the transmission antennas, creating spatial separation
- Cyclic delay diversity – deliberately delaying the signal of both antennas to create an artificial multipath.

Physical Channels	Transmit Diversity	Spatial Multiplexing	Cyclic Delay Diversity
Reference signal (RS)	No	No	No
Primary Sync Signal (P-SS)	No	No	No
Secondary Sync Signal (S-SS)	No	No	No
Broadcast (PBCH)	Yes	No	No
Control (PDCCH)	Yes	No	No
Hybrid ARQ Indication (PHICH)	Yes	No	No
Control Format Indicator (PCFICH)	Yes	No	No
Multicast (PMCH)	Yes	Yes	No
Shared (PDSCH)	Yes	Yes	Yes

Table 18. MIMO techniques applied to LTE downlink signals

In Tx Diversity and spatial multiplexing, signals are transmitted from two or more antennas. These signals shall be aligned. The time alignment error in Tx Diversity and spatial multiplexing transmission is specified as the delay between the signals from two antennas at the antenna ports.

The time alignment error in Tx Diversity or spatial multiplexing for any possible configuration of two transmission antennas shall not exceed 65 ns.

LTE assigns different positions of frequency and time of the reference signals (RS) transmitted from two different antennas, which is the basis of measuring the time alignment between the two antennas.

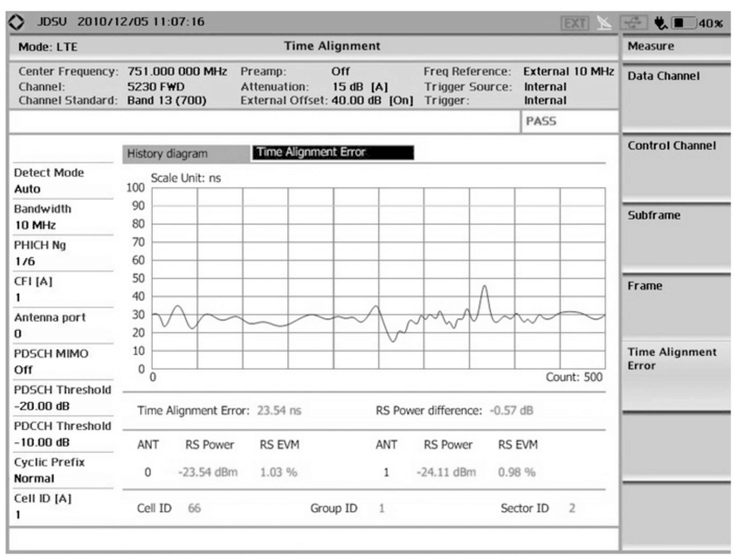


Figure 29. MIMO Time Alignment measurement

Unwanted Emission

For WCDMA, the unwanted emissions requirements as recommended in ITU-R SM.329 are applicable for frequencies that are smaller than 12.5 MHz away from the carrier center frequency. The 12.5 MHz value is derived as 250% of the necessary bandwidth (5 MHz for WCDMA) as per ITU-R SM.329. The frequency range within 250% of the necessary bandwidth around the carrier centre may be referred to as the Out Of Band (OOB) domain. Transmitter intermodulation distortions manifest themselves predominantly within the OOB domain and therefore more relaxed emission requirements, such as ACLR, are typically applied within the OOB domain.

In LTE, the channel bandwidth can range from 1.4 to 20 MHz. A similar scaling by 250% of the channel bandwidth would result in a large OOB domain for LTE: for the 20 MHz LTE channel bandwidth option, the OOB domain would extend to a large frequency range of up to ±5 MHz around the carrier center frequency.

To protect services in adjacent bands in a more predictable manner and to align with WCDMA, the LTE spurious domain is defined to start from 10 MHz below the lowest frequency of the eNB operating band and from 10 MHz above the highest frequency of the eNB operating band. The operating band plus 10 MHz on each side are covered by the LTE operating band unwanted emissions.

The following three measurements are performed to ensure the transmitter's quality:

- occupied bandwidth
- adjacent channel leakage ratio (ACLR)
- spectrum emission mask (SEM).

It is known that the following factors affect the unwanted emission characteristic of transmitters.

- intermodulation distortion (IMD)—LTE downlink signals are composed by a few tenths to thousands of subcarriers allocated with 15 kHz frequency spacing. Each subcarrier is mutually orthogonal for FFT processing, but due to inherent non-linearity, generation of intermodulation distortions is unavoidable. In addition to this, the high peak to average power ratio (PAR) characteristic of OFDM signals makes the effect more severe. Among the IMD signals, the 3rd IMD components are located near the transmission band affecting the adjacent channel. IMD shows the tendency to increase as the system ages and as the carrier is increased within the transmission band.
- harmonics—most transmitters have band pass filters at the end of the transmitter chain to suppress harmonics but due to filter limitations on the cut-off, some leakage signal is created. If the harmonics are in the receiver's band, it will cause severe QoS degradation.

Occupied Bandwidth

The occupied bandwidth is the width of a frequency band such that, below the lower and above the upper frequency limits, the mean power emitted are equal to a specified percentage ($\beta/2$) of the total mean transmitted power. The value of $\beta/2$ shall be taken as 0.5%.

The following figure shows the Base Station Analyzer Occupied Bandwidth measurement screen.

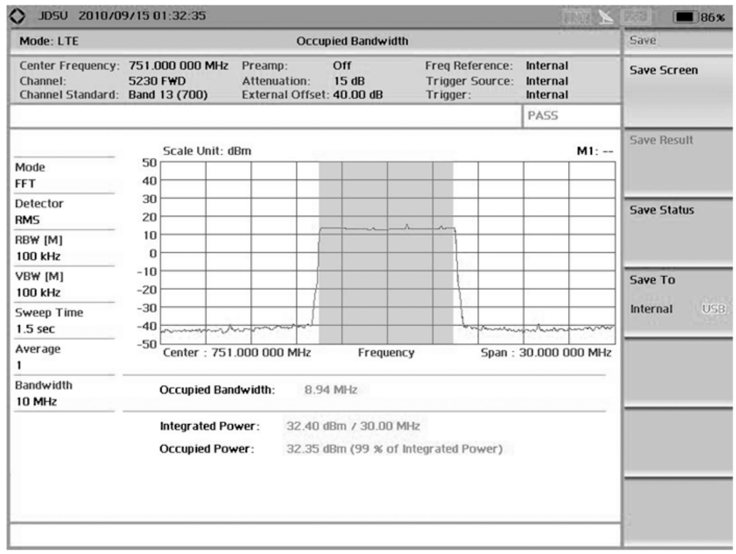


Figure 30. Occupied Bandwidth measurement (E-TM1.1)

In the Occupied Bandwidth function, the following parameters are set as default values on the Base Station Analyzer.

- RBW—100 kHz
- Attenuation—Auto.

The following settings may affect the measurement accuracy, thus some consideration must be taken.

- Freq. Offset—may affect the overall measurement accuracy
- RF In Loss—may affect the overall power measurement accuracy.

ACLR

Adjacent channel leakage power ratio (ACLR) is the ratio of the filtered mean power centered on the assigned channel frequency of the filtered mean power centered on an adjacent channel frequency. The requirements shall apply regardless of transmitter type (single carrier or multi-carrier).

For a multicarrier LTE eNB, the above definition applies to the lower edge of the carrier transmitted at the lowest carrier frequency and the higher edge of the carrier transmitted at the highest carrier frequency.

ACLR requirements are classified by the multiplexing scheme and filter type applied to the symbol shaping.

The following is the requirement for LTE-FDD systems using square filters:

LTE transmitted signal Signal channel bandwidth $BW_{channel}$ [MHZ]	eNB adjacent channel center frequency offset below the first or above the last carrier center frequency	Assumed adjacent channel carrier (informative)	Filter on the adjacent channel frequency and corresponding filter bandwidth	ACLR limit
1.4, 3.0, 5, 10, 15,	$BW_{Channel}$	LTE of same BW	Square (BW_{Config})	44.2dB
20	2 x $BW_{Channel}$	LTE of same BW	Square (BW_{Config})	44.2dB

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

Table 19. Base Station ACLR in paired spectrum

The following figure shows the Base Station Analyzer ACLR measurement screen for E-TM1.2 with 10MHz channel bandwidth. According to 3GPP recommendations for unwanted emission for out-of-band, ACLR measurement is performed across 50 MHz (± 250% of channel bandwidth) frequency bandwidth.

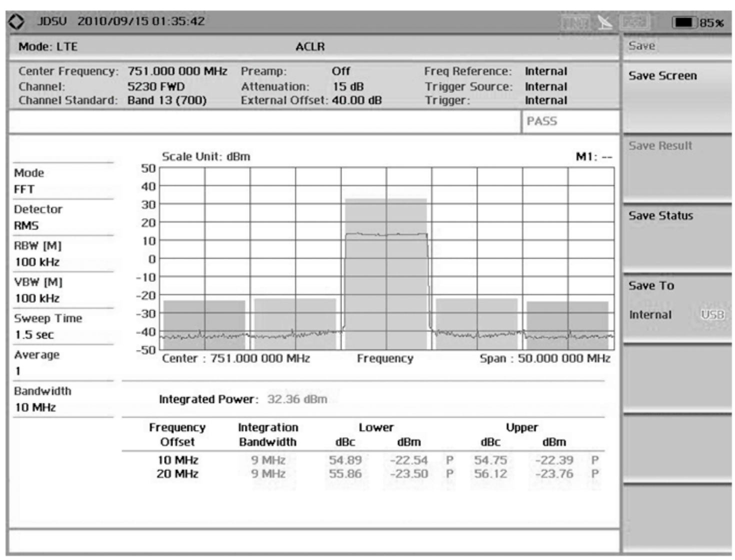


Figure 31. ACLR measurement screen (E-TM1.2)

The parameters presented in the measurement screen are defined as follows:

- Power Reference—the power of the main carrier under test measured over the transmission bandwidth (9 MHz)
- Freq Offset—the frequency difference between the center frequency and the neighboring channel
- dBc—the power difference between the power reference and the power of adjacent channel over the same bandwidth (9 MHz)
- dBm—the absolute power of adjacent channel over the integral bandwidth
- Lower—the adjacent channels located at the left (lower) side of the center frequency
- Upper—the adjacent channels located at the right (upper) side of the center frequency.

In case of a multi-carrier configuration, the measurement procedure is as follows:

- set the center frequency of the lowest carrier as the center frequency of the Base Station Analyzer, and measure the ACLR only for the lower side
- set the center frequency of the highest carrier as the center frequency of the JD7105A and measure the ACLR only for the upper side.

These two measurements verify the transmitter's performance.

In the ACLR function, the following parameters are set as default values on the Base Station Analyzer.

- RBW—100 kHz
- Attenuation—Auto.

The following settings may affect the measurement accuracy, thus some consideration must be taken.

- Freq. Offset—may affect the overall measurement accuracy
- RF In Loss—may affect the overall power measurement accuracy.

SEM

The Spectrum Emission Mask (SEM) measurement shows the operating band unwanted emissions. The limits of unwanted emission are defined from 10 MHz below the lowest frequency of the downlink operating band up to 10 MHz above the highest frequency of the downlink operating band.

The requirement shall apply regardless of the transmitter's type (single carrier or multicarrier). The unwanted emission limits in the downlink operating band that falls in the spurious domain are consistent with ITU-R recommendation SM.329.

For a multicarrier LTE eNB, the above definitions shall apply to the lower edge of the carrier transmitted at the lowest carrier frequency and the higher edge of the carrier transmitted at the highest carrier frequency.

According to ITU-R SM.329, unwanted emission varies depending on the eNB category and operating bands. The Base Station Analyzer adopts the SEM mask for 5, 10, 15 and 20 MHz downlink signals for operating bands beyond 2 GHz and for Category A as a default.

The following table shows the SEM requirement for 5, 10, 15 and 20 MHz LTE downlink signals for both Categories A of which the operating band is higher than 1 GHz.

Frequency offset of measurement filter -3dB point, Δf	**Frequency offset of measure filter center frequency, f_offset**	**Test requirement**	**RBW**
0 MHz ≤ Δf < 5 MHz	0.05 MHz ≤ Δ f_offset < 5.05	MHz	100 kHz
5 MHz ≤ Δf < 10 MHz	5.05 MHz ≤ f_offset < 10.05 MHz	-12.5 dBm	100 kHz
10 MHz ≤ Δf ≤ Δfmax	10.5 MHz ≤ f_offset < f_offsetmax	-13 dBm	1 MHz

Table 20. General operating band unwanted emission limits for 5, 10, 15 and 20 MHz channel bandwidth (E-UTRA bands) for Category A

The following figure shows the interval setting scheme for SEM measurement. While measuring SEM, the resolution bandwidth (RBW) is set as 100 kHz. The measurement bandwidth of 100 kHz was chosen to be of similar granularity as the bandwidth of any system with smaller radio resource allocation, for example, the bandwidth of one RB on LTE is 180 kHz and the bandwidth of a GSM carrier is 200 kHz. Since the -3 dB point is equal on the RBW filter bandwidth, the start point of the frequency offset is 50 kHz (1/2 of RBW filter bandwidth) apart from both ends of the channel bandwidth.

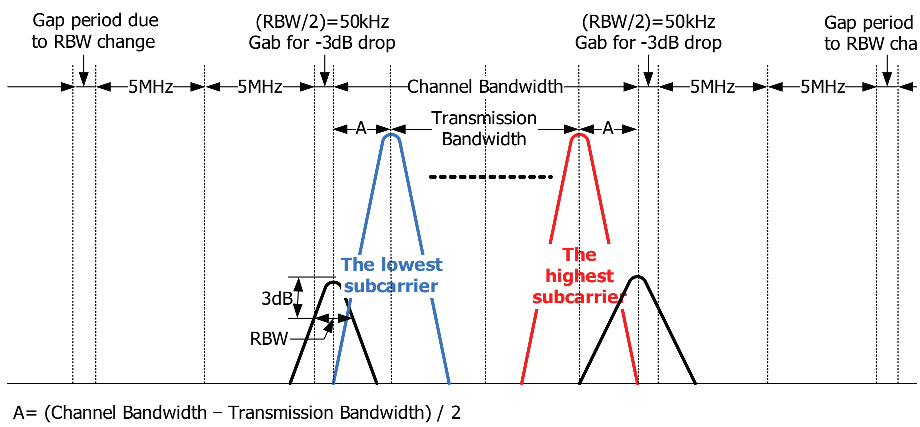


Figure 32. Definition of SEM sections

The following figure shows the Base Station Analyzer SEM measurement result:

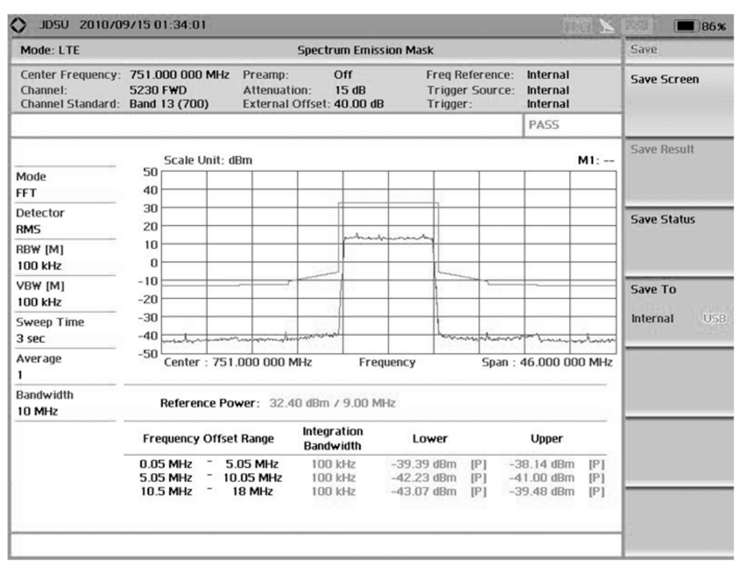


Figure 33. SEM measurement (E-TM1.1)

The SEM measurement parameters are defined as follows:

- Power reference—the channel power of the transmitted signal
- Start/Stop—the section of each SEM interval
- Freq—the frequency of the highest peak in the section
- Abs—the absolute power of the highest peak
- Rel—the power difference between the channel power and the power of the highest peak measured with 100 kHz RBW
- Pass/Fail—the condition whether the measurement violates the mask.

In the SEM function, the following parameters are set as default values on the Base Station Analyzer.

- RBW—100 kHz
- Attenuation—Auto.

The following settings may affect the measurement accuracy, thus some consideration must be taken.

- Freq. Offset—may affect the overall measurement accuracy
- RF In Loss—may affect the overall power measurement accuracy.

Over-the-Air Analysis

Over-the-air measurements provide signal quality at a specific location of the network. The two main metrics are as follows:

- ID Scanner – Measures the six strongest sites, verifying that the signal overlap among sites is that required for successful handovers
- Datagram – Measures all the resource blocks of the LTE downlink over time, providing an indicator of saturation at any given time
- Control channels – Measures the power level and modulation quality (EVM) of every control channel as well as power variations of the reference signal 0 (antenna 1) and reference signal 1 (antenna 2) under MIMO operation.

ID Scanner

The ID Scanner measures the six most powerful LTE signals at the measurement location providing a good indication of the signal overlap required for successful handovers.

For each LTE signal, it indicates the contents of the Physical Cell Identification in the form of Cell ID, Group ID and Sector ID. In addition, it performs a dominance measurement based on the power level of the primary and secondary synchronization channels (P-SCH and S-SCH) as well as the relationship they have with the entire LTE channel power.

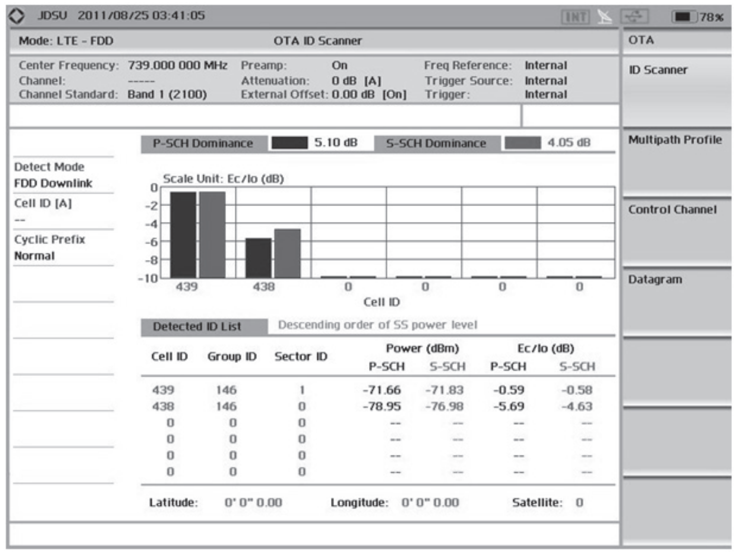


Figure 34. Over-the-Air ID Scanner

Datagram

The LTE datagram provides a power level activity of all the resource blocks contained in the LTE downlink signal through time, providing an indication of LTE's downlink data utilization at the measurement's location.

Figure 35. Over-the-Air Datagram Measurement

Control Channels

The measurement of control channels over the air provides the signal strength and modulation quality of a specified LTE base station at the measurement location.

The measurement covers the power- and modulation-quality metrics of all the control channels as well as two key MIMO measurements:

- Power level variation of the reference signal power of antenna-0 (RS0) and antenna-1 (RS1)
- Time alignment error between the reference signal of antenna-0 (RS0) and antenna-1 (RS1).

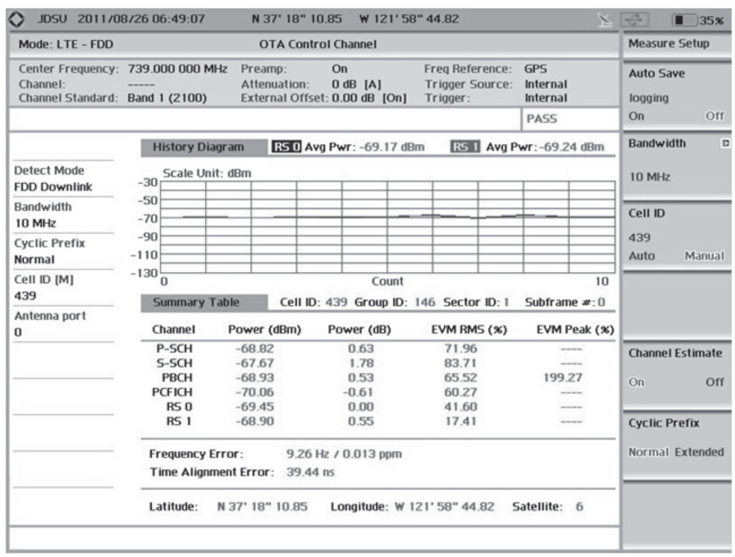


Figure 36. Over-the-Air Control Channel Measurement

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2. 3GPP TS 36.300. 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2 (Release 8).

3. 3GPP TS 36.104. 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception (Release 8).

4. LTE for UMTS - OFDMA and SC-FDMA Based Radio Access By Harri Holma, Antti Toskal

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