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Technical Report

3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Physical Layer Aspects for Evolved UTRA (Release 7)



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Keywords

Evolved UTRA, radio, packet mode, layer 1

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Foreword

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- z the third digit is incremented when editorial only changes have been incorporated in the document.

1 Scope

This document is related to the technical report for physical layer aspect of the study item “Evolved UTRA and UTRAN” [1]. The purpose of this TR is to help TSG RAN WG1 to define and describe the potential physical layer evolution under consideration and compare the benefits of each evolution techniques, along with the complexity evaluation of each technique.

This activity involves the Radio Access work area of the 3GPP studies and has impacts both on the Mobile Equipment and Access Network of the 3GPP systems.

This document is intended to gather all information in order to compare the solutions and gains vs. complexity, and draw a conclusion on way forward.

This document is a ‘living’ document, i.e. it is permanently updated and presented to TSG-RAN meetings.

Six basic L1 concept proposals are evaluated in this TR:

1. FDD UL based on SC-FDMA, FDD DL based on OFDMA
2. FDD UL based on OFDMA, FDD DL based on OFDMA
3. FDD UL/DL based on MC-WCDMA
4. TDD UL/DL based on MC-TD-SCDMA
5. TDD UL/DL based on OFDMA
6. TDD UL based on SC-FDMA, TDD DL based on OFDMA”

1.1 Rationale for RAN#30 decision on way forward for Evolved UTRA multiple access

The following has been considered by TSG-RAN #30 (Dec'05):

- When compared to the reference defined in TR 25.913, and based on the initial system-level evaluations with 5 MHz allocation, the spectral efficiency improvements achievable with a (CDMA-based) system according to an “evolutionary” approach and the spectral efficiency improvements achievable with a new approach (e.g. OFDM-based) are both attractive.
- Using a CDMA based approach enables smoother migration from prior UTRA releases and might offer more extensive physical layer reuse.
- On the other hand, a new Layer 1, with an inherent avoidance of a priori constraints in the air-interface design, allows for a more free choice of design parameters, making it easier to fulfil some of the E-UTRA targets e.g. latency requirements, finer minimum bandwidth granularity, commonality between different duplex modes.
- UE receiver processing is somewhat simpler for an OFDMA-based air interface; the attractiveness in terms of complexity increases with larger bandwidths and/or high order MIMO configurations.

Both approaches to the 3GPP radio-access evolution have their advantages and disadvantages, very much depending on the exact requirements.

On this basis, TSG-RAN #30 has decided that the Long-Term Evolution feasibility study will focus on OFDMA based downlink and SC-FDMA based uplink. TSG-RAN #30 has also re-affirmed that continued evolution of existing UTRA modes is an on-going necessary work activity within 3GPP.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.

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- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

- [1] 3GPP TD RP-040461: "Proposed Study Item on Evolved UTRA and UTRAN".
- [2] 3GPP, TR25.848, "Physical Layer Aspects of UTRA High Speed Downlink Packet Access."
- [3] 3GPP, TR25.896, "Feasibility Study for Enhanced Uplink for UTRA FDD"
- [4] 3GPP TR 25.913, "Requirements for evolved Universal Terrestrial Radio Access (UTRA) and Universal Terrestrial Radio Access Network (UTRAN)"
- [5] 3GPP, TR 25.942 V3.3.0 (2002-06), RF System Scenarios, June 2002
- [6] ETSI TR 101 112 (V3.1.0): "Universal Mobile Telecommunications System (UMTS); Selection procedures for the choice of radio transmission technologies of the UMTS (UMTS 30.03 version 3.1.0)."
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- [9] 3GPP, R1-040642, "Comparison of PAR and Cubic Metric for Power De-rating", Motorola
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- [14] Mohammed et al, "Characterization of Indoor Penetration Loss at ISM Band", Environmental Electromagnetics, 2003. CEEM 2003. Proceedings. 4-7 Nov. 2003, Page(s): 25-28.
- [15] Zhang and Hwang, "Measurements of the Characteristics of Indoor Penetration Loss", IEEE VTC 1994, 8-10 June 1994, Pages: 1741-1744 vol 3.

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply.

<defined term>: <definition>.

3.2 Symbols

For the purposes of the present document, the following symbols apply:

<symbol> <Explanation>

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

BS	Base Station
CP	Cyclic Prefix
DCT	Discrete Cosine Transform
DL	Downlink
DRX	Discontinuous Reception
DSCH	Downlink Shared Channel
DUSP	Switching point from downlink to uplink
E-DCH	Enhanced Dedicated Channel
E-UTRA	Evolved UTRA
E-UTRAN	Evolved UTRAN
FDD	Frequency Division Duplex
FDM	Frequency Division Multiplexing
FEC	Forward Error Correction
HARQ	Hybrid Automatic Repeat reQuest
HCR	High Chip Rate
HSDPA	High Speed Downlink Packet Access
IFFT	Inverse Fast Fourier Transform
IOTA	Isotropic Orthogonal Transform Algorithm
LCR	Low Chip Rate
LTE	Long Term Evolution
MBMS	Multimedia Broadcast Multicast Service
MIMO	Multiple Input Multiple Output
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
OQAM	Offset QAM
QoS	Quality of Service
PRB	Physical Resource Block
PS	Packet Switched
RF	Radio Frequency
SC-FDMA	Single Carrier – Frequency Division Multiple Access
SFN	Single Frequency Network
TDD	Time Division Duplex
UDSP	Switching point from uplink to downlink
UE	User Equipment
UL	Uplink
VRB	Virtual Resource Block

4 Introduction

At the 3GPP TSG RAN #26 meeting, the SI description on “Evolved UTRA and UTRAN” was approved [1].

The justification of the study item was, that with enhancements such as HSDPA and Enhanced Uplink, the 3GPP radio-access technology will be highly competitive for several years. However, to ensure competitiveness in an even longer time frame, i.e. for the next 10 years and beyond, a long-term evolution of the 3GPP radio-access technology needs to be considered.

Important parts of such a long-term evolution includes reduced latency, higher user data rates, improved system capacity and coverage, and reduced cost for the operator. In order to achieve this, an evolution of the radio interface as well as the radio network architecture should be considered.

Considering a desire for even higher data rates and also taking into account future additional 3G spectrum allocations the long-term 3GPP evolution should include an evolution towards support for wider transmission bandwidth than 5 MHz. At the same time, support for transmission bandwidths of 5MHz and less than 5MHz should be investigated in order to allow for more flexibility in whichever frequency bands the system may be deployed.

5 Requirements

(Editor’s note: we refer the related requirement in TR25.913)

6 General description of layer 1

6.1 Multiband operation

6.1.1 MC-WCDMA based proposal

By design, it is possible to deploy the MC-WCDMA system in all existing and future UTRA-FDD bands as well as new bands designated for cellular systems. The deployment can be made in either new carriers or in the same spectrum as existing carriers thus enabling simultaneous support for UTRA and E-UTRA UEs in the same spectrum allocation.

The multi-carrier approach is also well suited to simultaneous operation in multiple bands and over discontinuous allocations in the same band. Multi-band operation is primarily limited by the UE RF complexity and the laws of physics associated with the distance between the bands.

6.2 Duplexing

The E-UTRA air interface supports both frequency division duplex (FDD) and time division duplex (TDD) modes of operation.

The downlink and uplink concepts described in sections 7.1, 9.1 and 9.2 are common to FDD and TDD modes of operation unless otherwise stated (i.e. where specific properties/capabilities of FDD and TDD duplex arrangements need to be taken into account).

6.2.1 TDD mode aspects for OFDMA and SC-FDMA

In the TDD mode of E-UTRA, sub-frames can be assigned as either uplink sub-frames or downlink sub-frames (to accommodate different traffic profiles or different functions). A downlink or uplink sub-frame consists of an integer number of symbols (some of which may be idle to allow for timing advance) with a sub-frame structure that is defined by signaling from the network. The sub-frame structure may vary from sub-frame to sub-frame within the frame to accommodate different traffic profiles and latency requirements.

Downlink synchronisation reference signals and system information are contained in each frame and only occupy parts of the frame. If the synchronisation and system information signal structures are common to TDD and FDD modes, then it may be possible to realise some benefits in terms of UE complexity.

The traffic sub frame structure for TDD mode operation of E-UTRA is shown in Fig. 6.2.1-1. This structure supports timing advance for cells of various sizes.

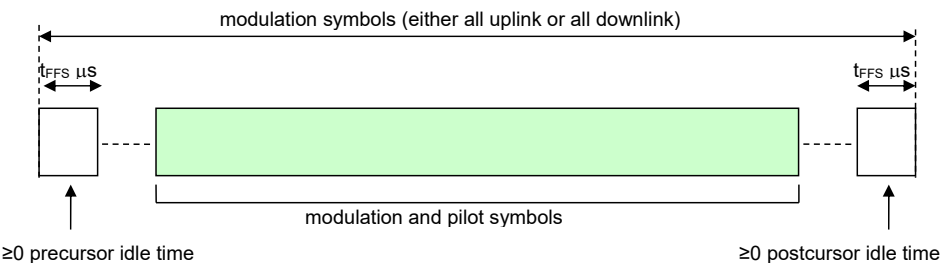


Figure 6.2.1-1 - Traffic timeslot structure TDD mode E-UTRA operation

In the TDD mode of operation common and / or dedicated pilots are used to help exploit channel reciprocity of the link. Distinct pilots from different antennas may be used to support multi-antenna techniques such as MIMO.

E-UTRA, when operating in TDD mode-of-operation, may face additional interference scenarios, compared to when operating in FDD mode of operation. More specifically, direct UE-to-UE and BS-to-BS interference may occur both within one carrier and between neighbour carriers.

If E-UTRA operates in TDD mode, two approaches have been proposed to meet the requirement on co-existence with current UTRA TDD according to TR 25.913. The possibility of adopting both the two approaches can be considered.

Approach 1 is described in section 6.2.1.1, and approach 2 is described in section 6.2.1.2. Either approach can be used depending on co-existence scenario.

In order to meet the latency requirement of TR25.913, it may be necessary to employ additional switching points in E-UTRA TDD compared to UTRA TDD. Any interference problem created as a result between the E-UTRA and the legacy carrier would need to be solved.

6.2.1.1 Approach 1 –Multiple fixed frame structures

According to approach 1, when there is a requirement for co-existence with LCR TDD, the frame structure described in section 6.2.1.1.1 can be used. When there is a requirement for co-existence with HCR TDD, the frame structure described in section 6.2.1.1.2 can be used.

6.2.1.1.1 For co-existence with LCR-TDD

Example of the first traffic sub-frame structure for TDD mode operation of E-UTRA is shown in Fig. 6.2.1-1. There is one pair of switching points within a 5ms E-UTRA radio sub-frame structure. Besides the first guard period set between the DwPTS and UpPTS, more guard periods can be provided by the uplink traffic time slot which follows the DL/UL switching point.

A guard period is required at a DL/UL or UL/DL switching point. Each traffic time slot should contain a small idle period (Timeslot Interval) which can be used for switching guard period from UL to DL traffic time slot. For the DL/UL switching point, if there is only one switching point between DL and UL traffic time slot in a E-UTRA TDD radio traffic time slot structure, a special guard period will be kept between the special downlink timeslot DwPTS and special uplink timeslot UpPTS.

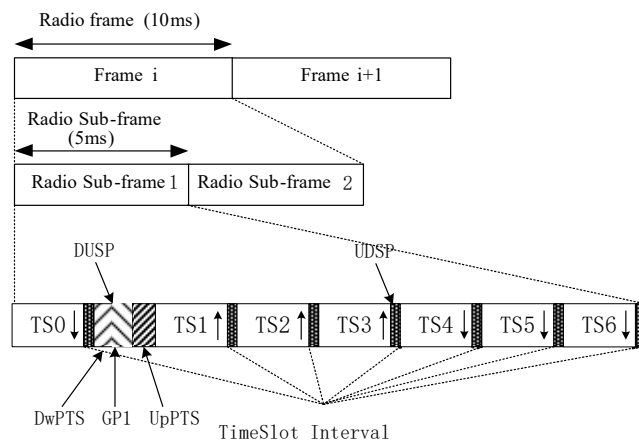


Figure 6.2.1.1-1 Frame Structure of one pair of switching points between DL and UL traffic timeslot

Assuming that a 10 ms frame is divided into 2 equally sized 5 ms radio sub-frames, one radio sub-frame consists of seven traffic time slots (TS0~TS6). The synchronization and guard period is between TS0 and TS1, whose duration is 0.275ms including DwPTS, GP and UpPTS. The TTI of E-UTRA TDD can be 0.675ms, the same as duration of one traffic time slot.

Note: as mentioned in Section 6.2.1, special considerations need to be taken with regards to the E-UTRA frame structure when operating in TDD mode of operation in order to satisfy the E-UTRA requirement on allowing for spectrum co-existence with current 3GPP TDD standards.

The minimum TTI for uplink transmission is equal to the uplink traffic timeslot duration (0.675ms).

A guard period is required at a DL/UL or UL/DL switching point. Each traffic time slot should contain a small idle period (Timeslot Interval) which can be used for switching guard period from UL to DL traffic time slot.

6.2.1.1.2 For co-existence with HCR-TDD

The framing structure of UTRA 3.84Mcps is based upon a radio frame of 10ms divided into 15 timeslots of equal duration ($\approx 666.667\mu\text{s}$). Each timeslot may be designated freely as uplink or downlink according to the system configuration.

To facilitate full alignment of the uplink and downlink transmission periods on an E-UTRA carrier with those of a 3.84Mcps TDD carrier for all possible UL/DL timeslot slot configurations, an E-UTRA sub-frame duration of $0.01/(15n)$ seconds is required, where $n = \{1, 2, 3, \dots\}$.

However, many common 3.84Mcps TDD deployments use a single switching point per radio frame. This, taken in conjunction with the fact that 3 HCR timeslots are of equal duration to $4 \times 0.5\text{ms}$ sub-frames for E-UTRA (see for example section 7.1.1, 9.1.1, 9.2.1), provides for further E-UTRA/UTRA TDD frame alignment possibilities when an E-UTRA sub-frame duration of 0.5ms is selected.

Thus, co-existence with HCR TDD is provided in one of two ways:

1. Via an E-UTRA sub-frame duration of $0.01/(15n)$ seconds. Each E-UTRA sub-frame within a 10ms radio frame may be configured as uplink or downlink
2. Via the use of the generic frame structure of 6.2.1.2 with 0.5ms sub-frame duration.

For reasons of commonality with the paired LTE mode, option 2 above is preferred.

6.2.1.2 Approach 2 –Generic frame structure

The second approach uses a generic frame structure to support backward compatibility with existing UTRA TDD systems. The frame structure is aligned with E-UTRA FDD.

HCR-TDD coexistence

The HCR-TDD timeslot duration $T_{\text{HCR-TDD}}$ is related to the E-UTRA sub-frame duration $T_{\text{E-UTRA}}$ of sections 7.1 and 9.1 / 9.2 according to the relationship:

$$3 \times T_{\text{HCR-TDD}} = 4 \times T_{\text{E-UTRA}} = 2\text{ms}$$

Hence, the E-UTRA uplink and downlink may be aligned with the HCR-TDD uplink and downlink provided that the HCR-TDD UL:DL timeslot split is of the form $3 \times n : 3 \times (5 - n)$, where n is an integer. In this case, the E-UTRA UL:DL split is $4 \times n : 4 \times (5 - n)$. An example alignment of the HCR-TDD frame to the E-UTRA frame is shown in Figure 6.2.1.2-1 for a 6:9 UL:DL timeslot split. The flexible frame structure of HCR-TDD allows existing HCR-TDD deployments to be migrated to a $3 \times n : 3 \times (5 - n)$ timeslot split in readiness for a future E-UTRA deployment in an adjacent carrier. As per the LCR-TDD case, idle symbols / sub-frames may be inserted into the E-UTRA carrier when the HCR-TDD carrier does not utilise a $3 \times n : 3 \times (5 - n)$ UL:DL split.

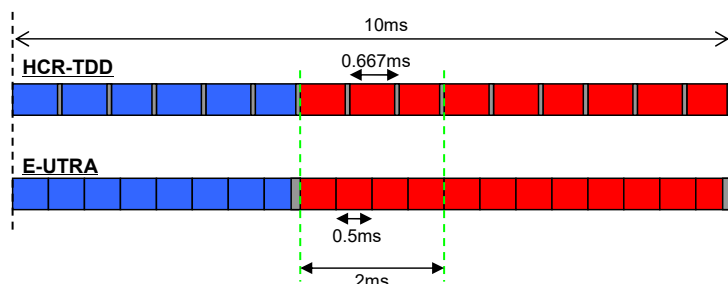


Figure 6.2.1.2-1 - E-UTRA / HCR-TDD co-existence example for 6:9 UL: DL timeslot split

LCR-TDD coexistence

Coexistence between LCR-TDD and E-UTRA may be facilitated by inserting either idle symbols within the E-UTRA frame (these are required for the purposes of timing advance in any case) or idle sub-frames (which may either be inserted by the E-UTRAN scheduler dynamically or their existence may be signalled on the broadcast control channel). Applying a delay or frame offset between the LCR-TDD frame and the E-UTRA frame may allow the time allocated to idle symbols / sub-frames to be minimised. Figure 6.2.1.2-2 shows how coexistence between LCR-TDD with a 3:3 UL:DL traffic timeslot split and E-UTRA (operating in a TDD mode with the numerology of sections 7.1 and 9.1 / 9.2) can be facilitated. To increase spectral efficiency, the idle sub-frame of Figure 6.2.1.2-2 could be replaced by 4 data symbols followed by 3 idle symbols. Similarly, Figure 6.2.1.2-3 shows facilitation of coexistence of between LCR-TDD with a 2:4 UL:DL traffic timeslot split and E-UTRA. Note that the idle sub-frame shown in Figure 6.2.1.2-2 is only required for an adjacent E-UTRA carrier. For a non-adjacent E-UTRA carrier, the idle E-UTRA sub-frame can be replaced by either a downlink E-UTRA sub-frame or an uplink E-UTRA sub-frame.

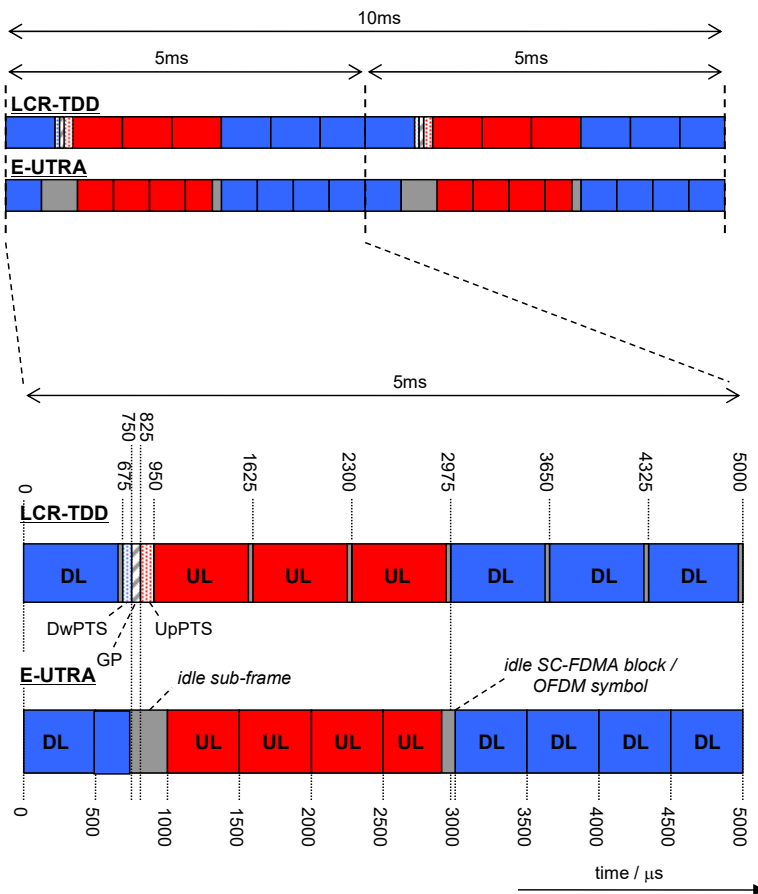


Figure 6.2.1.2-2 - E-UTRA / LCR-TDD co-existence example for 3:3 UL: DL timeslot split

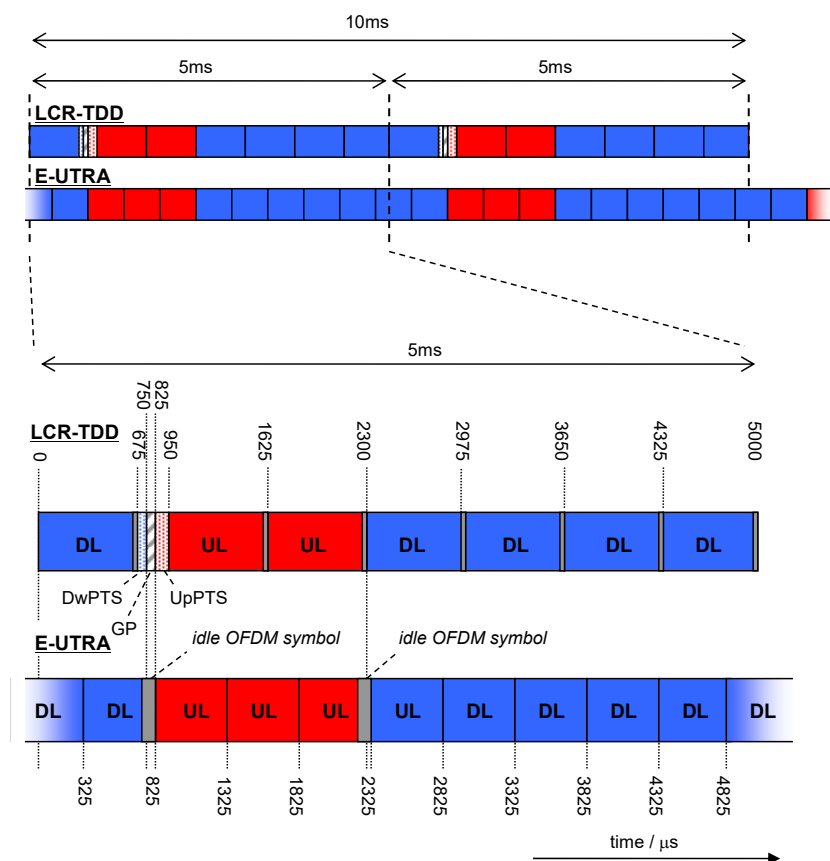


Figure 6.2.1.2-3 - E-UTRA / LCR-TDD co-existence example for 2:4 UL: DL timeslot split

In the case where there are no coexistence issues, this frame structure degenerates to the frame structure of Figure 6.2.1.2-4. This figure is for illustrative purposes only. Idle symbols are required only at DL/UL switching points. The idle period, required in the Node B at UL/DL switching points, is created by timing advance means.

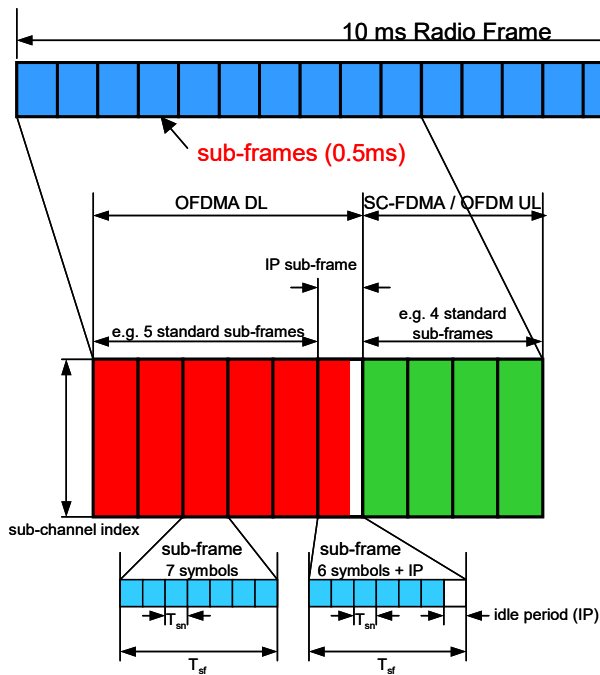


Figure 6.2.1.2-4: frame structure when there are no coexistence issues

6.2.2 Duplexing for the MC-WCDMA based proposal

One of the driving motivations for the MC-WCDMA based proposal is to ensure maximum re-use of the UTRA-FDD access technology in order to minimize the incremental development efforts and allow for deployment in the same spectrum as existing UTRA-FDD systems. The MC-WCDMA based E-UTRA proposal therefore relies on frequency division duplexing for uplink and downlink transmissions and is primarily geared towards usage of paired band allocations.

6.2.2.1 Unpaired spectrum use cases

It is feasible to use unpaired band allocations with the MC-WCDMA based E-UTRA as follows:

- Use the unpaired band allocation for the downlink only transmission of the physical channels in support of E-MBMS; this enables standalone usage of the unpaired spectrum, possibly in time multiplexed manner with legacy UTRA-TDD deployments.
- Use the unpaired band allocation as additional downlink or uplink carriers to support asymmetric multi-carrier configurations.
- Pair various unpaired band allocations.

6.2.2.2 Time duplex operation

As shown during the original UMTS selection phase in the former ETSI SMG2 group, the MC-WCDMA based E-UTRA could also be defined in such a way that it would allow half duplex operation and full time duplex operation.

It would be possible to introduce these new modes of operation as part of the MC-WCDMA based proposal. However, this would require significant changes to the original UTRA-FDD channel structure, timing and procedures and would therefore not benefit in the same way from the UTRA-FDD learning curve.

A more natural approach which is consistent with the underlying backward compatibility philosophy is therefore to consider the existing UTRA-TDD modes and their multi-carrier evolution for standalone time duplex operation in unpaired spectrum allocations.

7 Downlink concepts

Three basic concepts are proposed in downlink:

1. OFDMA (FDD / [TDD])
2. MC-WCDMA (FDD)
3. MC-TD-SCDMA (TDD)

7.1 OFDMA (FDD / [TDD])

7.1.1 Basic transmission scheme

The downlink transmission scheme is based on conventional OFDM using a cyclic prefix, with a sub-carrier spacing $\Delta f = 15$ kHz and a cyclic-prefix (CP) duration $T_{CP} \approx 4.7/16.7 \mu s$ (short/long CP). Assuming that a 10 ms radio frame is divided into 20 equally sized sub-frames (of which, in case of TDD operation, a subset is allocated for downlink transmission), this parameter set implies a sub-frame duration $T_{sub-frame} = 0.5$ ms. The basic transmission parameters are then specified in more detail in Table 7.1.1-1 below. It may be noted that numerology specified below are for evaluation purpose only.

Table 7.1.1-1 - Parameters for downlink transmission scheme

Transmission BW	1.25 MHz	2.5 MHz	5 MHz	10 MHz	15 MHz	20 MHz
Sub-frame duration	0.5 ms					
Sub-carrier spacing	15 kHz					
Sampling frequency	1.92 MHz ($1/2 \times 3.84$ MHz)	3.84 MHz	7.68 MHz (2×3.84 MHz)	15.36 MHz (4×3.84 MHz)	23.04 MHz (6×3.84 MHz)	30.72 MHz (8×3.84 MHz)
FFT size	128	256	512	1024	1536	2048
Number of occupied sub-carriers†, ††	76	151	301	601	901	1201
Number of OFDM symbols per sub frame (Short/Long CP)	7/6					
CP length (μs /samples)	Short	$(4.69/9) \times 6$, $(5.21/10) \times 1^*$	$(4.69/18) \times 6$, $(5.21/20) \times 1$	$(4.69/36) \times 6$, $(5.21/40) \times 1$	$(4.69/72) \times 6$, $(5.21/80) \times 1$	$(4.69/108) \times 6$, $(5.21/120) \times 1$
	Long	$(16.67/32)$	$(16.67/64)$	$(16.67/128)$	$(16.67/256)$	$(16.67/384)$
		$(16.67/144) \times 6$, $(5.21/160) \times 1$				

†Includes DC sub-carrier which contains no data

†† This is the assumption for the baseline proposal. Somewhat more carriers may be possible to occupy in case of the wider bandwidth

*: $\{(x1/y1) \times n1, (x2/y2) \times n2\}$ means $(x1/y1)$ for $n1$ OFDM symbols and $(x2/y2)$ for $n2$ OFDM symbols

The sub-frame duration corresponds to the minimum downlink TTI. The possibility to concatenate multiple sub-frames into longer TTIs, e.g. for improved support for lower data rates and QoS optimization, should be considered. In this case, the TTI can either be a semi-static or dynamic transport channel attribute. In case of a semi-static TTI, the TTI is set through higher layer signalling. In case of a dynamic TTI, the number of sub-frames concatenated can be dynamically varied for at least the initial transmission and possibly for retransmissions. It is to be determined to what extent a dynamic TTI can reduce higher layer protocol overhead (e.g. MAC, RLC), L1 overhead (e.g. CRC), and ACK/NACK feedback, as well as reducing latency by reducing segmentation of IP packets. It is initially assumed that the Network (e.g. Node-B) would signal the TTI, either explicitly (e.g. with L1 bits) or implicitly (e.g. by indicating modulation and coding rate and transport block size). The interaction between dynamic TTI, signaling errors, HARQ procedure (time synchronous vs. asynchronous including adaptive or non-adaptive characteristics) and UE complexity needs to be investigated.

Note that the sub-carrier spacing is constant regardless of the transmission bandwidth. To allow for operation in differently sized spectrum allocations, the transmission bandwidth is instead varied by varying the number of OFDM sub-carriers. The necessity for supporting an additional longer cyclic-prefix duration, see Table 7.1.1-1, is under consideration. The longer cyclic prefix should then target multi-cell broadcast and very-large-cell scenarios.

The mapping and indexing of N available physical channel symbols (sub-carriers) in one OFDM symbol in RF spectrum should be done as illustrated in figure below

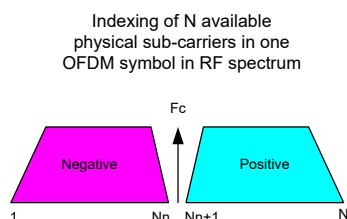


Figure 7.1.1-1: Mapping of physical channel symbols in frequency domain

According numerology in Table 7.1.1-1, N is 75/150/300/600/900/1200 and N_n is 37/75/150/300/450/600 when transmission BW is 1.25/2.5/5/10/15/20 MHz respectively.

For E-UTRA TDD, the frame structure corresponding to Table 7.1.1-1 is supported. In addition, a second frame structure is also supported with the intention of providing co-existence with LCR UTRA TDD. The sampling frequency, FFT size, sub-carrier spacing, and number of occupied sub-carriers is the same as for Table 7.1.1-1. However, with this alternative frame structure, a 10 ms radio frame is divided into 2 equally sized 5 ms sub-frames¹ (of which a subset is allocated for downlink transmission), one sub-frame consists of seven traffic time slots (TS0~TS6) and three special time slots, and one example is shown in Figure 6.2.1.1-1. The synchronization and guard period is between TS0 and TS1, whose duration is 0.275ms. Each time slot should contain a small idle period (Timeslot Interval) which can be used for switching guard period from UL to DL time slots. The basic transmission parameters for this alternative frame structure are specified in Table 7.1.1-2 below.

Table 7.1.1-2 - Parameters for downlink transmission scheme (alternative TDD frame structure)

Transmission BW	1.25 MHz	2.5 MHz	5 MHz	10 MHz	15 MHz	20 MHz
Timeslot duration	0.675 ms					
Sub-carrier spacing	15 kHz					
Sampling frequency	1.92 MHz ($1/2 \times 3.84$ MHz)	3.84 MHz	7.68 MHz (2×3.84 MHz)	15.36 MHz (4×3.84 MHz)	23.04 MHz (6×3.84 MHz)	30.72 MHz (8×3.84 MHz)

¹ Note that the term “sub-frame” is, in this case, aligned to the LCR UTRA TDD terminology and not to the terminology currently used for E-UTRA. The E-UTRA term “sub-frame” corresponds to the term “time slot” used here.

FFT size		128	256	512	1024	1536	2048
Number of occupied sub-carriers†, ††		76	151	301	601	901	1201
Number of OFDM symbols per Timeslot (Short/Long CP)		9/8					
CP length (μs/samples)	Short	7.29/14	7.29/28	7.29/56	7.29/112	7.29/168	7.29/224
	Long	16.67/32	16.67/64	16.67/128	16.67/256	16.67/384	16.67/512
Timeslot Interval (samples)	Short	18	36	72	144	216	288
	Long	16	32	64	128	192	256

†Includes DC sub-carrier which contains no data

†† This is the assumption for the baseline proposal. Somewhat more carriers may be possible to occupy in case of the wider bandwidth

7.1.1.1 Modulation scheme

7.1.1.1.1 Basic modulation scheme

Supported downlink data-modulation schemes are QPSK, 16QAM, and 64QAM.

Extension to hierarchical modulation schemes for broadcast should be considered.

7.1.1.1.2 Enhanced modulation scheme

As an alternative to conventional OFDM, OFDM with pulse shaping (OFDM/OQAM) should be studied.

7.1.1.1.2.1 OFDM/OQAM overview

Contrary to conventional OFDM modulation, OFDM/OQAM modulation does not require a guard interval (also called cyclic prefix). For this purpose, the prototype function modulating each sub-carrier must be very well accurately localized in the time domain, to limit the inter-symbol interference for transmissions over multipaths channels.

This prototype function can be also accurately localized in the frequency domain, to limit the inter-carrier interferences (due to Doppler effects, phase noise...). This function must also guarantee orthogonality between sub-carriers both in time and frequency domains.

It is mathematically proven that when using complex valued symbols, the prototype functions guaranteeing perfect orthogonality at critical sampling rate can not be well localised both in time and frequency. For instance the unity function used in conventional OFDM has weak frequency localisation properties and obliges using a cyclic prefix between the symbols to limit inter-symbol interference.

To let the use of accurately localised functions in the time-frequency domain OFDM/OQAM introduced a time offset between the real part and the imaginary part of the symbols. Orthogonality is then guaranteed only over *real* values. The corresponding multi-carrier modulation is an OFDM/OQAM. The OFDM/OQAM transmitted signal is expressed as

$$s(t) = \sum_n \sum_{m=0}^{M-1} a_{m,n} e^{j2\pi m v_0 t} g_{m,n}(t) \quad (7.1.1.1.2-1)$$

where $a_{m,n}$ denotes the *real valued* information value (can be the real part or the imaginary part of the Offset complex QAM symbol) sent on the m^{th} sub-carrier at the n^{th} symbol, M is the number of sub-carriers, v_0 is the inter-carrier spacing, it is the same of the classical OFDM system. τ_0 is the OFDM/OQAM symbol duration, it is equal to $T_u/2$ (T_u is the OFDM symbol duration), and g is the prototype function.

It is important to notice that OFDM/OQAM symbol rate is twice the classical OFDM symbol rate without cyclic prefix ($\tau_0 = T_u/2$), meanwhile, since the modulation used is a real one, the information amount sent by an OFDM/OQAM symbol is half the information amount sent by an OFDM symbol. Figure 7.1.1.1.2-1 depicts the signal generation chain of an OFDM/OQAM signal.

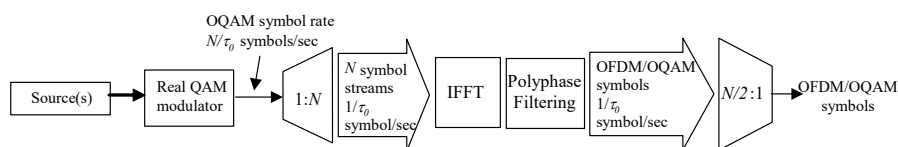


Figure 7.1.1.1.2-1: OFDM/OQAM Signal Generation Chain

The modulator generates N real valued symbols, each τ_0 where $\tau_0 = T_u / 2$. The real valued symbols are then dephased, they are multiplied by $e^{j\pi n}$ before the IFFT as it is noted in (7.1.1.1.2-1). Figure 7.1.1.2 shows the time-frequency localisation of the transmitted symbols both for conventional OFDM using complex valued QAM symbols and for OFDM/OQAM.

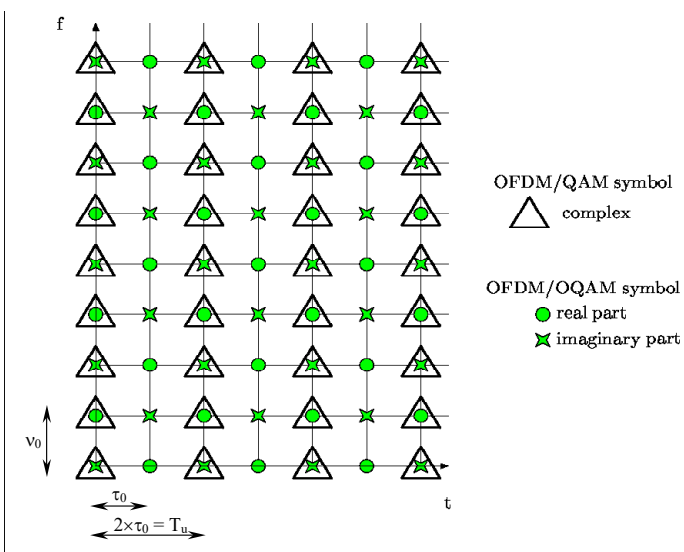


Figure 7.1.1.2-2: OFDM/OQAM time and frequency lattices (compared to conventional OFDM w/o guard interval)

The main difference of OFDM/OQAM over conventional OFDM signal generation stays in the filtering by the prototype function g after the IFFT, instead of the cyclic prefix addition.

Thanks to the Inverse Fourier Transform, the prototype function g can be implemented in its polyphase form, which reduces strongly the complexity of the filtering. Moreover the density 2 induces some more simplifications in the polyphase implementation. Figure 7.1.1.2-3 shows a possible polyphase implementation of both an OFDM/OQAM modulator and demodulator (G_i are the polyphase components of the prototype filter).

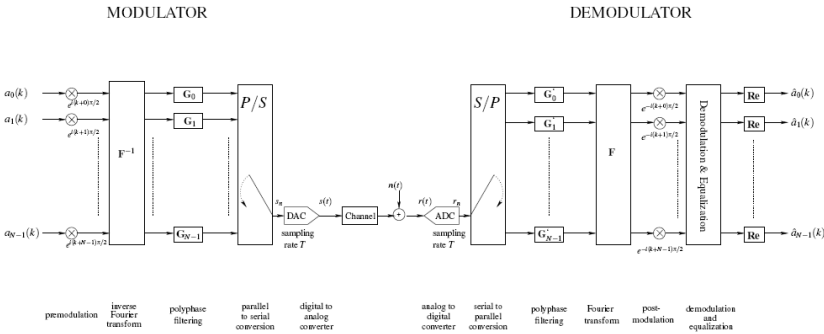


Figure 7.1.1.2-3: OFDM/OQAM polyphase implementation

One candidate for OFDM/OQAM filter (g) is IOTA (Isotropic Orthogonal Transform Algorithm) prototype obtained by orthogonalizing the Gaussian function in both time and frequency domains according to Schmidt method. See Figure 7.1.1.2-4.

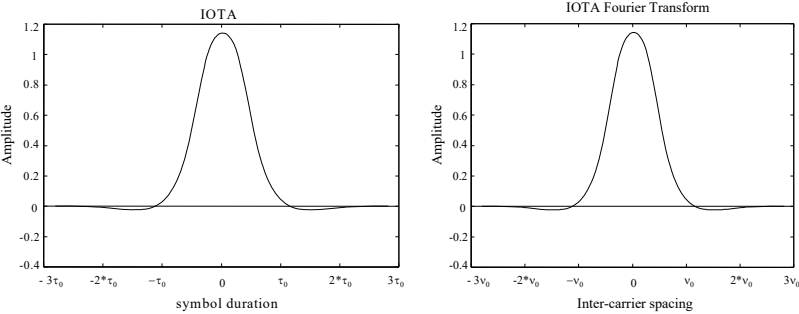


Figure 7.1.1.2-4: Temporal and spectral representation of the IOTA prototype filter

Another particularity of IOTA is the spectrum of the generated signal. Thanks to its good frequency localisation, the resulting spectrum is steeper than for conventional OFDM. Figure 7.1.1.2-5 depicts the resulting spectra of the signals generated by both rectangular filter used in classical OFDM system and IOTA function used for OFDM/OQAM system. FFT length is 512 and 300 sub-carriers are modulated (parameters corresponding to the 5 MHz case)

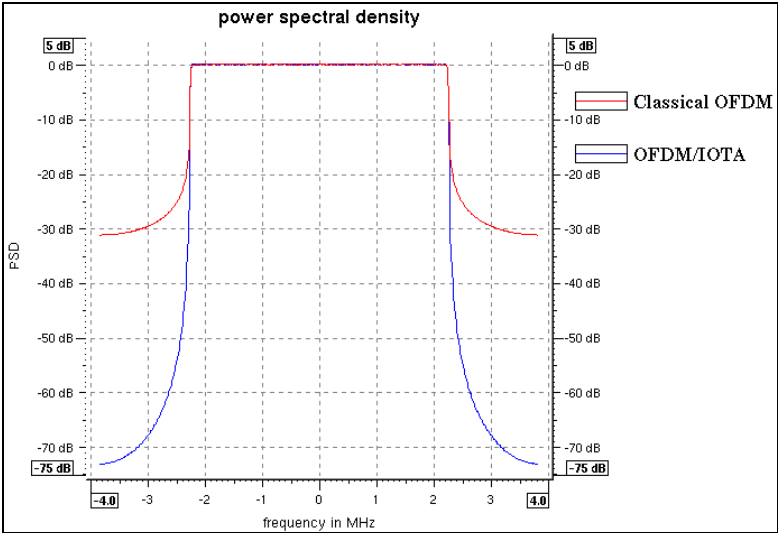


Figure 7.1.1.1.2-5: OFDM/IOTA and conventional OFDM spectra

7.1.1.1.2.2 OFDM/OQAM transmission scheme

The OFDM/OQAM transmission scheme is very similar to the conventional OFDM scheme listed in Table 7.1.1-1, with a sub-carrier spacing $\Delta f = 15$ kHz. Assuming that a 10 ms radio frame is divided into 20 equally sized sub-frames, this parameter set implies a sub-frame duration $T_{\text{sub-frame}} = 0.5$ ms. As for conventional OFDM it may be noted that numerology specified below are for evaluation purpose only. All remarks regarding the support of concatenated TTI remain relevant.

Table 7.1.1.1.2-1 – OFDM/OQAM parameters for downlink transmission scheme

Transmission BW	1.25 MHz	2.5 MHz	5 MHz	10 MHz	15 MHz	20 MHz
Sub-frame duration	0.5 ms					
Sub-carrier spacing	15 kHz					
Sampling frequency	1.92 MHz (1/2 × 3.84 MHz)	3.84 MHz	7.68 MHz (2 × 3.84 MHz)	15.36 MHz (4 × 3.84 MHz)	23.04 MHz (6 × 3.84 MHz)	30.72 MHz (8 × 3.84 MHz)
FFT size	128	256	512	1024	1536	2048
Number of occupied sub-carriers†, ††	76	151	301	601	901	1201
Number of OQAM symbols per sub frame	15*					
CP length	0					

†Includes DC sub-carrier which contains no data

†† This is the assumption for the baseline proposal. Somewhat more carriers may be possible to occupy in case of the wider bandwidth

*: In OFDM/OQAM the symbol rate is twice higher than for conventional OFDM (if no CP was included) and the amount of information transmitted per OFDM/OQAM symbol is half the amount transmitted by 1 conventional OFDM symbol (see section 7.1.1.1.2.1 for more details)

7.1.1.2 Multiplexing including reference-signal structure

7.1.1.2.1 Downlink data multiplexing

The channel-coded, interleaved, and data-modulated information [Layer 3 information] is mapped onto OFDM time/frequency symbols. The OFDM symbols can be organized into a number of *physical* resource blocks (PRB) consisting of a number (M) of consecutive sub-carriers for a number (N) of consecutive OFDM symbols. The granularity of the resource allocation should be able to be matched to the expected minimum payload. It also needs to take channel adaptation in the frequency domain into account. The size of the baseline physical resource block, S_{PRB} , is equal to $M \times N$, where $M=25$ and N is equal to the number of OFDM symbols in a subframe (the presence of reference symbols or control information is ignored here to simplify the description). This results in the segmentation of the transmit bandwidth shown in Table 7.1.1.2.1-1.

Table 7.1.1.2.1-1 Physical resource block bandwidth and number of physical resource blocks dependent on bandwidth.

Bandwidth (MHz)	1.25	2.5	5.0	10.0	15.0	20.0
Physical resource block bandwidth (kHz)	375	375	375	375	375	375
Number of available physical resource blocks	3	6	12	24	36	48

Using other values such as, e.g. $M=15$ or $M=12$ or $M=10$ or M equal to other values can be considered based on the outcome of the interference coordination study.

The frequency and time allocations to map information for a certain UE to resource blocks is determined by the Node B scheduler and may e.g. depend on the frequency-selective CQI (channel-quality indication) reported by the UE to the Node B, see Section 7.1.2.1 (time/frequency-domain channel-dependent scheduling). The channel-coding rate and the modulation scheme (possibly different for different resource blocks) are also determined by the Node B scheduler and may also depend on the reported CQI (time/frequency-domain link adaptation).

Both block-wise transmission (localized) and transmission on non-consecutive (scattered, distributed) sub-carriers are also to be supported as a means to maximize frequency diversity. To describe this, the notion of a *virtual* resource block (VRB) is introduced. A virtual resource block has the following attributes:

- Size, measured in terms of time-frequency resource.
- Type, which can be either 'localized' or 'distributed'.

All localized VRBs are of the same size, which is denoted as S_{VL} . The size S_{VD} of a distributed VRB may be different from S_{VL} . The relationship between S_{PRB} , S_{VL} and S_{VD} is FFS.

Distributed VRBs are mapped onto the PRBs in a distributed manner. Localized VRBs are mapped onto the PRBs in a localized manner. The exact rules for mapping VRBs to PRBs are FFS.

The multiplexing of localized and distributed transmissions within one subframe is accomplished by FDM.

As a result of mapping VRBs to PRBs, the transmit bandwidth is structured into a combination of localized and distributed transmissions. Whether this structuring is allowed to vary in a semi-static or dynamic (i.e. per subframe) way is FFS. The UE can be assigned multiple VRBs by the scheduler. The information required by the UE to correctly identify its resource allocation must be made available to the UE by the scheduler. The number of signalling bits required to support the multiplexing of localized and distributed transmissions should be optimized.

Details of the multiplexing of lower-layer control signaling is currently TBD but may be based on time, frequency, and/or code multiplexing.

7.1.1.2.2 Downlink reference-signal structure

The downlink reference signal(s) can be used for at least

- Downlink-channel-quality measurements
- Downlink channel estimation for coherent demodulation/detection at the UE

- Cell search and initial acquisition

The basic downlink reference-signal structure, consisting of known *reference symbols*, is illustrated in Figure 7.1.1.2.2-1.

Reference symbols (a.k.a. "*First reference symbols*") are located in the first OFDM symbol of every sub-frame assigned for downlink transmission. This is valid for both FDD and TDD as well as for both long and short CP.

Additional reference symbols (a.k.a. "*Second reference symbols*") are located in the third last OFDM symbol of every sub-frame assigned for downlink transmission. This is the baseline for both FDD and TDD as well as for both long and short CP. However, it should be evaluated if, for FDD, the second reference symbols are needed.

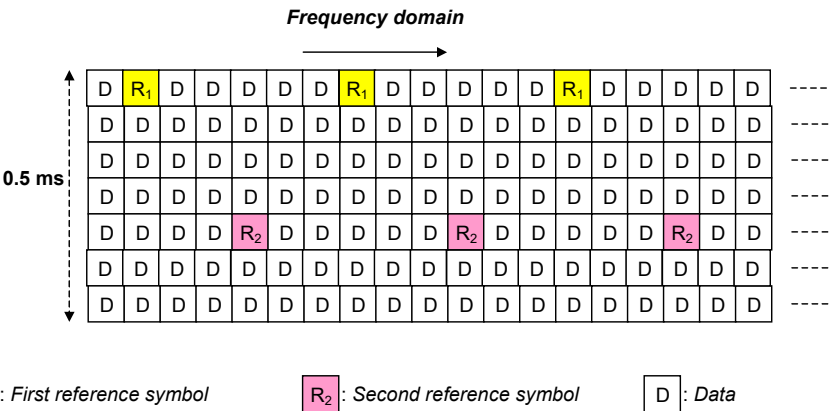


Figure 7.1.1.2.2-1. Basic downlink reference-signal structure¹

¹ This figure assumes 7 OFDM symbols per sub frame according to Table 7.1.1-1 (short CP). In case of long CP or frame structure according to Table 7.1.1-2, the figure should be modified accordingly.

The spacing (in the frequency domain) between reference symbols of the same OFDM symbol and antennas is $M = 6$ sub-carriers [*also other values of M could be studied*]. The first and second reference symbols are staggered in the frequency domain as illustrated in Figure 7.1.1.2.2-1 above

The current assumption is that the position (in the frequency domain) of the reference symbols *may* vary from sub-frame to sub-frame and between cells. However, this assumption may be reconsidered if it is in conflict with any future conclusions regarding the E-UTRA cell-search procedure.

In the case that Layer 1 downlink control signaling (more specifically signaling or part of the signaling related to downlink and uplink scheduling) is located at the beginning of the corresponding sub-frame (still TBD if this will be the case or if the Layer 1 signaling is to be spread over the sub-frame), it is currently assumed that demodulation of this information could be carried out without using the second reference symbols of the corresponding sub-frame (however, second reference symbols of previous sub-frames may be used if available).

~~Possible transmission of additional UE-specific downlink reference symbols are to be considered for dynamic beam-forming or MIMO. Also, whether the above reference-signal-structure should be directly applicable to SFN-based multi-cell multicast/broadcast or if some additions/extensions in this case are needed is FFS.~~

It should be possible to create multiple mutually orthogonal downlink reference signals.

- To support transmission using multiple TX antennas within one cell (up to a maximum of 4 orthogonal reference signals should be supported to enable higher-order downlink MIMO) within one cell/beam. Note that, for TDD, orthogonal reference signals may not be needed between TX antennas of the same Node B if the multiple TX antennas are used for downlink dynamic beam forming.

- To allow for orthogonal reference signals between sectors and fixed beams of the same Node B.

Orthogonality between reference signals of different TX antennas of the same cell/beam is created by means of FDM. This implies that the reference-signal structure of Figure 7.1.1.2.2-1, with different antenna-specific frequency shifts, is valid for each antenna. CDM should be evaluated as an alternative.

In case of orthogonality between reference signals of different cells/beams belonging to the same Node B, the orthogonality is created in the code domain, i.e. the (frequency domain) sequence of reference symbols are multiplied by mutually orthogonal patterns. [The assumption regarding CDM-based orthogonality between reference signals of cells/beams of the same Node B is to be confirmed by means of system-level evaluation.]

Possible transmission of additional UE-specific downlink reference symbols are to be considered for dynamic beam forming or MIMO.

Furthermore, to provide channel estimates for coherent demodulation of multi-cell MBMS transmission, the following approaches are to be considered:

- Cell-common reference signals (transmitted only in the sub-frames in which MBMS is transmitted).
- Cell-specific reference signals, together with group scrambling.

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7.1.1.2.3 Downlink L1/L2 Control Signaling

The downlink outband control signaling consists of

- scheduling information for downlink data transmission,
- scheduling grant for uplink transmission, and
- ACK/NAK in response to uplink transmission.

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Transmission of control signaling from these groups is mutually independent, e.g., ACK/NAK can be transmitted to a UE regardless of whether the same UE is receiving scheduling information or not.

7.1.1.2.3.1 Downlink Scheduling Information

Downlink scheduling information is used to inform the UE how to process the downlink data transmission. The information signalled to a UE scheduled to receive user data is summarized in Table 7.1.2.3.1-1.

The possible downlink time/frequency location(s) for category 1 information is known to the UE a priori.

The category 3 information is transmitted for every TTI of data to the scheduled user(s).

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Table 7.1.2.3.1-1 Downlink scheduling information required by a UE

	Field	Size	Comment
Cat. 1 (Resource indication)	ID (UE or group specific)	8-9	Indicates the UE (or group of UEs) for which the data transmission is intended
	Resource assignment	FFS	Indicates which (virtual) resource units (and layers in case of multi-layer transmission) the UE(s) shall demodulate.
	Duration of assignment	2-3	The duration for which the assignment is valid, could also be used to control the TTI or persistent scheduling.
Cat. 2 (transport format)	Multi-antenna related information	FFS	Content depends on the MIMO/beamforming schemes selected.
	Modulation scheme	2	QPSK, 16QAM, 64QAM. . In case of multi-layer transmission, multiple instances may be required.

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	Payload size		6	Interpretation could depend on e.g. modulation scheme and the number of assigned resource units (c.f. HSDPA). In case of multi-layer transmission, multiple instances may be required.
Cat. 3 (HARQ)	If asynchronous hybrid ARQ is adopted	Hybrid ARQ process number	3	Indicates the hybrid ARQ process the current transmission is addressing.
		Redundancy version	2	To support incremental redundancy.
		New data indicator	1	To handle soft buffer clearing.
	If synchronous hybrid ARQ is adopted	Retransmission sequence number	2	Used to derive redundancy version (to support incremental redundancy) and ‘new data indicator’ (to handle soft buffer clearing).

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Note: It is FFS whether asynchronous or synchronous hybrid ARQ operation will be adopted.

Note: In case of multi-layer transmission to a UE, multiple instances of (parts of) category 2 and category 3 information may be required.

Note: It is FFS whether information about multi-layer transmission is included in 'resource assignment' or 'multi-antenna related information'.

7.1.1.2.3.2 Uplink Scheduling Grant

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Uplink scheduling grants are used to assign resources to UEs for uplink data transmission. The information signalled to a UE receiving an uplink scheduling grant is summarized in Table 7.1.1.2.3.2-1. The modulation and coding scheme to use for uplink transmission is implicitly given by the resource assignment and the transport format.

Table 7.1.1.2.3.2-1 Uplink scheduling grant for a UE

Field		Size	Comment
Resource assignment	ID (UE or group specific)	8-9	Indicates the UE (or group of UEs) for which the grant is intended
	Resource assignment	FFS	Indicates which uplink resources, localized or distributed, the UE is allowed to use for uplink data transmission.
	Duration of assignment	2-3	The duration for which the assignment is valid. The use for other purposes, e.g., to control persistent scheduling, 'per process' operation, or TTI length, is FFS.
TF	Transmission parameters	FFS	The uplink transmission parameters (modulation scheme, payload size, MIMO-related information, etc) the UE shall use. If the UE is allowed to select (part of) the transport format, this field sets determines an upper limit of the transport format the UE may select.

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Note: It is FFS whether the transport format the UE uses is mandated by the Node B or controlled by the UE.

7.1.1.2.3.3 ACK/NAK

The hybrid ARQ feedback in response to uplink data transmission consists of a single ACK/NAK bit.

Table 7.1.1.2.3.3-1 ACK/NAK for a UE.

Field	Size	Comment
ACK/NAK	FBS	Up to one bit per uplink transport block. Multiple bits may be required to support uplink multi-layer transmission (if hybrid ARQ operates per layer) and in case of TDD.

7.1.1.3 Channel coding and physical channel mapping

Current assumption for the study-item evaluations should be that channel coding for “normal” data [*Layer 3 information*] is based on UTRA release 6 Turbo coding, possibly extended to lower rates by extension with additional code polynomials, extended longer code blocks, and modified by the removal of the tail. However, the use of alternative FEC encoding schemes could also be considered, especially if significant benefits in terms of complexity and/or performance can be shown.

To achieve high processing gain, repetition coding can be used as a complement to FEC.

Channel coding for lower-layer control signaling is TBD.

7.1.1.4 MIMO and Transmit Diversity

The baseline antenna configuration for MIMO is two transmit antennas at the cell site and two receive antennas at the UE. The possibility for higher-order downlink MIMO (four TX/RX antennas) should also be considered.

Since control channel performance can be difficult to improve through other sources of diversity (retransmission, link adaptation, etc.), open loop transmit diversity schemes should be considered for the downlink control channels. The open loop transmit diversity can also be considered for the downlink unicast traffic. Transmit diversity schemes vary with respect to their complexity and ability to support a variable number of transmit antennas. Therefore, the simplicity and scalability of transmit diversity schemes should be compared as well as their performance gains. Open loop block code-based transmit diversity, cyclic shift diversity, and combined space-time (or space-frequency) block code/cyclic shift diversity techniques should be considered.

7.1.1.4.1 Aspects for LTE MIMO

Aspects to consider for LTE MIMO discussions are as follows:

- Micro-cellular/Hot-spot and macro cellular environments should be considered in performance evaluation
- Not increase number of operation modes unnecessarily. Impact on receiver architecture should also be considered
- Realistic assumptions have to be taken into account when comparing different MIMO concepts, such as feedback errors and delays, needed multi-antenna reference signal overhead and its effect on performance, complexity and signalling requirements etc. The resulting reference signal and signalling overheads in both uplink and downlink have to be justified by the shown improvements

7.1.1.4.2 High level principles of MIMO for unicast traffic

Spatial division multiplexing (SDM) of multiple modulation symbol streams to a single UE using the same time-frequency(-code) resource is supported. When a MIMO channel is solely assigned to a single UE, it is known as single user (SU)-MIMO.

Other high level principles are as the followings:

- Maximum antenna configuration for evaluation is 4x4.

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- Multiple codewords (including single codeword as a special case) that use the same time-frequency(-code) resource and are independently channel-coded with independent CRC should be investigated. Possible values for the maximum number of codewords per resource block transmitted by the Node B are 1, 2, 3, or 4. Possible values for the maximum number of codewords that can be received by the UE are 1, 2, 3, or 4
- In addition to the SDM, the spatial division multiplexing of the modulation symbol streams for different UEs using the same time-frequency(-code) resource is supported for evaluation, which may be denoted as spatial division multiple access (SDMA) or multi-user (MU)-MIMO. Note that the SDM is a special case of the SDMA.
- Use of pre-coding as a means to convert the antenna domain MIMO signal processing into the beam domain processing should be investigated. It is FFS whether the precoding should be unitary or non-unitary. Because precoding might require less complex (linear) receivers to achieve a given level of performance, both the receiver complexity requirements and the performance of MIMO algorithms should be considered. Any additional feedback required for precoding and any additional related computational complexity in the UE should also be taken into account..
- Rank adaptation (and/or the antenna subset selection), of which exact implementation is FFS, is supported for evaluation as a means to prevent possible performance loss from using higher number of MIMO layers than can be supported by the channel condition.
- An open loop transmit diversity should be investigated as an alternative mode of MIMO operation than the one requiring MIMO-specific feedback from the UE.
- Followings are identified as candidates for the UE feedback information but not limited to:
 - o MIMO channel state information, which may be used by the Node B to determine MIMO processing consisting of e.g., selection of the rank (and/or the antenna subset), and/or the pre-coding, etc.
 - o If, for TDD operation, uplink reference signals should be transmitted to provide channel state information to support downlink MIMO transmission.
 - o Channel quality indicator (CQI), which may be used by the Node B to decide a MCS level(s). In addition to the CQI, another form of feedback signalling, which may be similar to the feedback information (FBI) as defined from Rel-99, should be considered as a candidate feedback signalling.
 - o If multiple operation modes are defined, e.g. MIMO and open loop transmit diversity,, and an open loop MIMO are supported, it may be needed for a UE to inform the Node B of the indication of (preferred) operation mode.

7.1.1.4.3 High level principles of MIMO for E-MBMS broadcast traffic

The MIMO transmission for the broadcast traffic should be discussed noting that

- in E-MBMS broadcast, there will be a single or multiple transmitting Node B's and multiple receiving UE's
- feedback signalling from the UE may not be feasible.

In the absence of any feedback from the UEs in E-MBMS, the potential candidates for MIMO are either an open-loop transmit diversity scheme, an open-loop spatial multiplexing approach or a hybrid combination of both. Any form of additional transmit diversity is not expected to bring any significant benefit if the number of SFN cells is large enough, because E-MBMS already enjoys from frequency-diversity due to delayed signals received from multiple cells. However, E-MBMS service becomes bandwidth limited in an SFN operation and therefore spatial-multiplexing techniques become attractive. Moreover, the received signal from multiple cells sees increasing decorrelation in an E-MBMS environment which also favors spatial-multiplexing.

Both single code word and multi-code word spatial multiplexing schemes are considered in the study item phase. In case of multi-code word spatial multiplexing, dynamic adaptation of modulation and coding etc. for each code word is not possible due to absence of channel quality feedback. However, different code words can potentially use different modulation and coding and/or power offsets etc. in a semi-static fashion in order to enable efficient interference cancellation at the UE receiver. Since the baseline UE has only two antennas, the number of broadcast codewords are limited to two. E-MBMS for UE's limited to single codeword reception capability should be further considered. E-MBMS signals from Node B's with more than two transmit antennas should be transparent to the UE.

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7.1.1.5 Downlink macro diversity

Fast cell selection is one option for macro-diversity for unicast data.. In principle, Intra-Node-B selection should be able to operate on a sub-frame basis while the "speed" of inter-Node-B cell selection will depend on the outcome of discussions on Evolved UTRAN architecture.

An alternative Intra-Node-B macro diversity scheme for unicast is a simultaneous multi-cell transmission with soft-combining. The basic idea of multi-cell transmission is that, instead of avoiding interference at the cell border by means of inter-cell-interference coordination, both cells are used for transmission of the same information to a UE thus reducing inter-cell interference as well as improving the overall available transmit power. Another possibility of intra-Node-B multi-cell transmission is to explore the diversity gain between the cells with space-time processing (e.g. by employing STBC through two cells). Assuming Node-B-controlled scheduling and that fast/tight co-ordination between different Node B is not feasible, multi-cell transmission should be limited to cells belonging to the same Node B

Two alternatives for multi-cell transmission have been proposed,

- Alternative #1
The same reference signal pattern is used for the transmissions from the two cells. In this case, from a UE point-of-view the multi-cell transmission will be identical to a single-cell transmission using a different antenna pattern,
- Alternative #2
Different reference signal patterns are used for the transmission from the two cells.

The impact of the two alternatives on the reference signal design and overhead, if any, needs further investigations.

For multi-cell broadcast, soft combining of radio links should be supported, assuming a sufficient degree of inter-Node-B synchronization, at least among a sub-set of Node B's. Mechanisms should be supported in E-UTRAN that allow the network to adapt which cells are in an SFN that will transmit an MBMS service that may be soft combined.

7.1.1.6 MBMS

MBMS transmissions may be performed in the following two ways:

- Multi-cell transmissions
- Single-cell transmissions

In case of single-cell transmission, the MBMS traffic channel (MTCH) can be mapped to the DL shared data channel (DL-SCH). In case of multi-cell transmissions, the MTCH may be mapped to another transport channel type.

In case of multi-cell transmission the cells and content are synchronised to enable for the terminal to combine the energy from multiple transmissions without additional receiver complexity. Tight inter-cell synchronization, in the order of substantially less than the cyclic prefix, is assumed in order for the UE to be able to combine multi-cell MBMS transmissions. Also, in case of cell-common reference signals, the reference symbol design needs to be such that those reference symbols needed for MBMS reception are identical in all cells to be considered for combining.

One dimension of the MBMS design is whether the MBMS transmission is actually sharing the same carrier with unicast traffic or not. For instance, for mobile TV, MBMS data can be sent on a separate carrier not carrying anything other than broadcast/MBMS related information. In that case, the MBMS design shall be able to efficiently benefit from such a situation.

It is desirable to have MBMS transmissions at high instantaneous data rates so that low transmission duty cycle per MBMS "channel" (source content) enables low power consumption for MBMS capable UEs. This may impose some requirements in the multiplexing of different multicast source contents at the physical layer. For the case of multiplexing unicast and multicast traffic within the same carrier, enabling low UE power consumption should be considered in the evaluation of the unicast/multicast multiplexing schemes depicted below.

In case of multiplexing MBMS transmissions with unicast traffic within the same carrier:

- Inter-sub frame TDM and
- intra-sub-frame FDM of unicast and multicast traffic

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should be investigated. In both cases, intra-sub-frame multiplexing with DL L1/L2 control channel should be supported. DL L1/L2 signalling associated with uplink data transmissions, e.g. scheduling grants and HARQ ACK may need to be transmitted in every DL sub-frame. The exact multiplexing of such L1/L2 signalling with the multicast transmission is FFS.

When there is no unicast data traffic in sub-frames carrying MBMS, it is to be considered if all the reference signals of Figure 7.1.1.2.2-1 need to be transmitted. In case that not all the reference signals are transmitted in certain sub frames, the impact on L1/L2 control, CQI and synchronization performance needs to be carefully evaluated.

It is to be considered if limiting unicast and multicast transmission multiplexing to inter-sub-frame TDM within a 10 MHz bandwidth would lead to a simplified channel structure without significantly impacting efficiency.

The associated L1/L2 control channel for MTCH may be transmitted less frequently than the associated L1/L2 control channel for DL-SCH.

In case of multiplexing MBMS transmissions is handled using a separate carrier

- There is only TDM multiplexing between different services
- Only long CP is considered for evaluation
- Bandwidths of 5 and 10 MHz are considered for evaluation

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7.1.2 Physical layer procedure

7.1.2.1 Scheduling

The Node B scheduler (for unicast transmission) dynamically controls which time/frequency resources are allocated to a certain user at a given time. Downlink control signaling informs UE(s) what resources and respective transmission formats have been allocated. The scheduler can instantaneously choose the best multiplexing strategy from the available methods; e.g. frequency localized or frequency distributed transmission. The flexibility in selecting resource blocks and multiplexing users (7.1.1.2) will influence the available scheduling performance. Scheduling is tightly integrated with link adaptation (7.1.2.2) and HARQ (7.1.2.3). The decision of which user transmissions to multiplex within a given sub-frame may for example be based on

- QoS parameters and measurements,
- payloads buffered in the Node-B ready for scheduling,
- pending retransmissions,
- CQI reports from the UEs,
- UE capabilities,
- UE sleep cycles and measurement gaps/periods,
- system parameters such as bandwidth and interference level/patterns,
- etc.

Methods to reduce the control signaling overhead, e.g., pre-configuring the scheduling instants (persistent scheduling) and grouping for conversational services, should be considered. In addition it should be determined if grouping can more efficiently use time frequency resources resulting in higher capacity.

7.1.2.2 Link adaptation

Link adaptation (AMC: adaptive modulation and coding) with various modulation schemes and channel coding rates is applied to the shared data channel. The same coding and modulation is applied to all groups of resource blocks belonging to the same L2 PDU scheduled to one user within one TTI and within single stream (i.e., different modulation schemes and coding rates may be applied to different streams in case of MIMO). This applies to both localized and distributed transmission.

The overall coding and modulation is illustrated in Figure 7.1.2.2-1

The use of power and modulation adaptation per resource block is FFS.

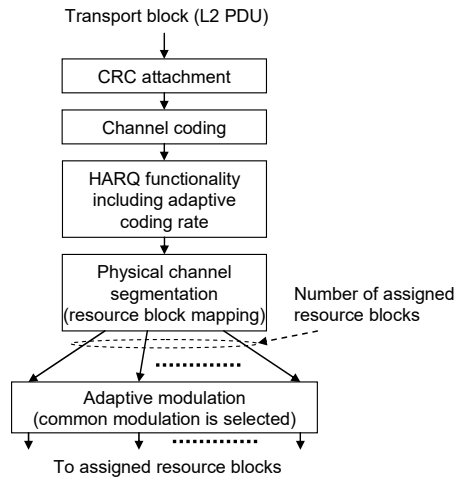


Figure 7.1.2.2-1 – Resource block-common adaptive modulation and resource block-common channel coding rate scheme (for localized and distributed transmission modes).

7.1.2.3 HARQ

Downlink hybrid ARQ (HARQ) should be based on Incremental Redundancy. Note that Chase Combining is a special case of Incremental Redundancy and is thus implicitly supported as well.

The N-channel Stop-and-Wait protocol is used for downlink HARQ.

HARQ can be classified as being synchronous or asynchronous:

- Synchronous HARQ implies that (re)transmissions for a certain HARQ process are restricted to occur at known time instants. No explicit signaling of the HARQ process number is required as the process number can be derived from, e.g., the sub-frame number.
- Asynchronous HARQ implies that (re)transmissions for a certain HARQ process may occur at any time. Explicit signaling of the HARQ process number is therefore required.

In principle, synchronous operation with an arbitrary number of simultaneous active processes at a time instant could be envisioned. In this case, additional signaling may be required. Asynchronous operation already supports an arbitrary number of simultaneous active processes at a time instant. Furthermore, note that, in a synchronous scheme, the transmitter may choose not to utilize all possible retransmission instants, e.g., to support pre-emption. This may require additional signaling.

The various forms of HARQ schemes are further classified as adaptive or non-adaptive in terms of transmission attributes, e.g., the Resource Block (RB) allocation, Modulation and transport block size, and duration of the retransmission. Control channel requirements are described for each case.

- Adaptive implies the transmitter may change some or all of the transmission attributes used in each retransmission as compared to the initial transmissions (e.g. due to changes in the radio conditions). Hence, the associated control information needs to be transmitted with the retransmission. The changes considered are:
 - o Modulation
 - o Resource Block allocation
 - o Duration of transmission

- Non-Adaptive implies that changes, if any, in the transmission attributes for the retransmissions, are known to both the transmitter and receiver at the time of the initial transmission. Hence, the associated control information need not be transmitted **forwith** the retransmission.

With those definitions, the HS-DSCH in WCDMA uses an adaptive, asynchronous HARQ scheme, while E-DCH in WCDMA uses a synchronous, non-adaptive HARQ scheme.

The capability of adaptively being able to change the packet format (i.e., adaptive IR) and the transmission timing (i.e., asynchronous IR) yields an adaptive, asynchronous IR based HARQ operation. Such a scheme has the potential of optimally allocating the retransmission resources in a time varying channel. For each HARQ retransmission, control information about the packet format needs to be transmitted together with the data sub-packet.

Synchronous HARQ transmission entails operating the system on the basis of a predefined sequence of retransmission packet format and timing.

The benefits of synchronous HARQ operation when compared to asynchronous HARQ operation are:

- Reduction of control signalling overhead. from not signalling the HARQ channel process number.
- Lower operational complexity if non-adaptive operation is chosen.
- Possibility to soft combine control signalling information across retransmissions for enhanced decoding performance if non-adaptive operation is chosen.

Depending on the actual L1/L2 requirements, asynchronous HARQ may best address the issues of:

- Scheduling flexibility if fully adaptive operation is selected and if both localized and distributed allocations are selected.
- Support for multiple simultaneous (in the same (set of) sub-frame(s)) independent HARQ processes
- Flexibility in scheduling of retransmissions

The desirability of particular L1/L2 features will determine the degree of adaptive operation.

7.1.2.4 Cell search

7.1.2.4.1 Purposes of the SCH, BCH, and reference symbols and information to be detected in the cell search

E-UTRA cell search is assumed to be based on two signals ("channels") transmitted in the downlink, the "SCH" (Synchronization Channel) and "BCH" (Broadcast Channel).

The primary purpose of the SCH is to enable acquisition of the received timing, i.e., at least the SCH symbol timing, and frequency of the downlink signal. The UE can obtain the remaining cell/system-specific information from the BCH, SCH and also from some additional channels, such as the reference symbols. The primary purpose of the BCH is to broadcast a certain set of cell and/or system-specific information similar to the current UTRA BCH transport channel.

Aside from the SCH symbol timing and frequency information, the UE must acquire at least the following cell-specific information.

- The overall transmission bandwidth of the cell
- Cell ID
- Radio frame timing information when this is not directly given by the SCH timing, i.e., if the SCH is transmitted more than once every radio frame, see Section 7.1.2.4.2 for further information.
- Information regarding the antenna configuration of the cell (number of transmitter antennas)
- Information regarding the BCH bandwidth if multiple transmission bandwidths of the BCH are defined, see also Section 7.1.2.4.3
- CP length information regarding the sub-frame in which the SCH and/or BCH are transmitted

Each set of information is detected by using one or several of the SCH, reference symbols, or the BCH.

The information regarding the overall transmission bandwidth of the cell can directly indicate the BCH bandwidth since the BCH bandwidth in relation to the transmission bandwidth of the cell is pre-specified. To facilitate Cell ID detection, several options in embedding the Cell ID into the SCH are possible. For example, the Cell ID may be directly mapped

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into the SCH, or different Cell ID information may be group-wised. For the case of group ID, cell ID group index can be detected using the SCH, and the Cell IDs within the detected Cell ID group can be detected using reference symbols or the BCH. As an alternative approach, information regarding the BCH bandwidth and CP length may be detected by blind detection from the SCH or BCH, by using hypothesis testing for example.

Detailed information conveyed by the SCH, reference symbols, and BCH should be studied during SI₁.

7.1.2.4.2 Structure in time

Figure 7.1.2.4.2-1 shows different possibilities for the basic transmission timing of the downlink SCH and BCH during one radio frame. The SCH and BCH are transmitted one or multiple times every 10-msec radio frame. Note that the numbers of SCHs and BCHs per radio frame may not be the same, as can be seen in the lowest part of Fig. 7.1.2.4.2-1. The BCH is placed at a well-defined time instant after/before the downlink SCH by the time delay/advance of τ . The number of SCH and BCH transmissions per radio frame should be studied from the viewpoints of detection probability, cell search time including inter-radio access technology (RAT) measurement for various mobility conditions, and impact on the TDD mode. For the TDD mode, multiple SCH and/or BCH transmissions per radio frame may lead to undesirable restrictions on the TDD framing structure and the set of possible UL/DL asymmetries may be reduced. This is especially true for lower numbers of switching points per frame. For the LCR TDD based frame structure (Figure 6.2.1.1-1), the SCH is transmitted in downlink special time slot DwPTS, and the BCH is transmitted in the TS0 timeslot, for every 5-msec radio sub-frame.

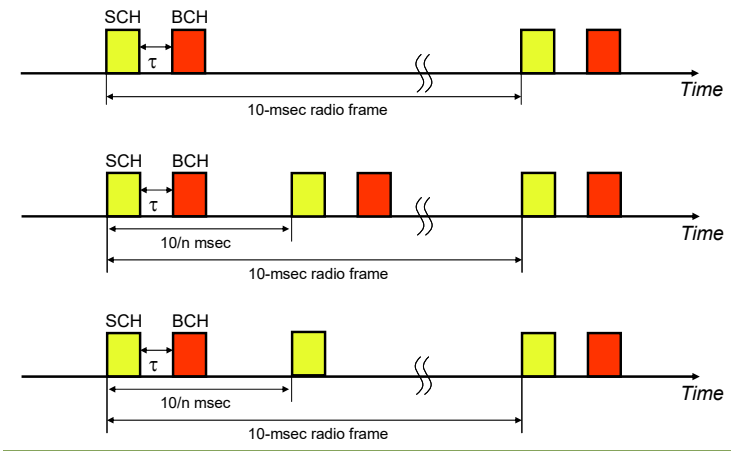


Figure 7.1.2.4.2-1 – Basic transmission timing of downlink SCH and BCH during one radio frame. Please note that this figure is for illustrative purposes only and is not meant to specify the number of SCHs and BCHs per radio frame.

The position of the SCH transmission timing within a sub-frame should be fixed in all sub-frames to which the SCH is multiplexed and the spacing of the sub-frame with the SCH should be constant, in order to allow a simple averaging of the correlations over multiple sub-frames. To achieve constant SCH transmission timing within a sub-frame, the following three SCH symbol multiplexing methods should be investigated.

- SCH symbol multiplexing on the last OFDM symbol within a sub-frame
- SCH symbol multiplexing on the first OFDM symbol within a sub-frame and mandating a short CP length for that OFDM symbol when both short and long CP lengths are used in a cell
- Mandatory usage of the same CP length (either short CP or long CP) for all the sub-frames to which the SCH is multiplexed, along with possible restrictions on the multiplexing of the MBMS channel

Figure 7.1.2.4.2-2 shows the first method. The SCH should be multiplexed into the last OFDM symbol within a 0.5-msec sub-frame. This leads to a fixed SCH symbol transmission timing regardless of the CP length. This configuration

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achieves sub-frame timing detection without the knowledge of the CP length at the UE. It also allows for a simple averaging of the correlation values over multiple sub-frames. The first method allows flexible CP length allocation, i.e., allocation of long and short CPs to any sub-frame without restrictions from the SCH detection perspective. On the other hand, using this approach, restrictions on the UL/DL switching point for TDD are necessary in the case that the DTX of the last part of the downlink sub-frames is used for creation of the TDD guard time.

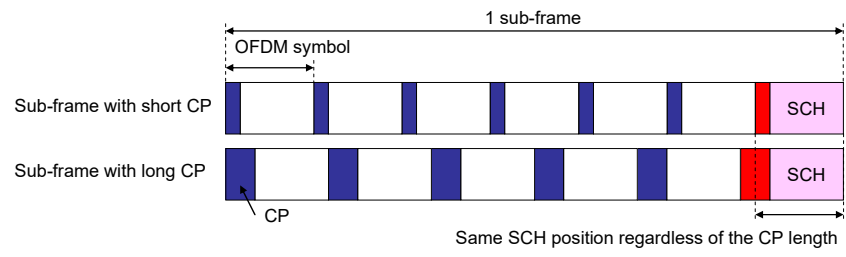


Figure 7.1.2.4.2-2 Basic transmission timing of downlink SCH within sub-frame in the first method. Please note that this figure is for illustrative purposes only.

Figure 7.1.2.4.2-3 shows the second method. In the second method, an SCH symbol is multiplexed into the first OFDM symbol within a sub-frame and a short CP is used for that OFDM symbol regardless of the CP length for the other OFDM symbols within that sub-frame. This method also leads to a fixed SCH symbol transmission timing at the UE and allows flexible CP length allocation and a flexible UL/DL switching point for the TDD mode. On the other hand, the necessity for SFN reception of the SCH from multiple cells, and the decoding procedure and transmission performance of the other channels mapped on the first OFDM symbol with the SCH should be investigated further since the second method cannot apply a long CP to the SCH when applying a short CP to unicast while applying a long CP to broadcast for SFN reception.

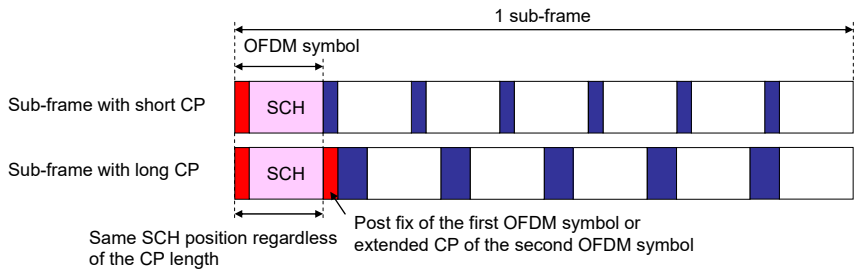


Figure 7.1.2.4.2-3 – Basic transmission timing of the downlink SCH within a sub-frame in the second method. Please note that this figure is for illustrative purposes only.

On the other hand, in the third method, an SCH symbol is multiplexed into any OFDM symbol within any sub-frame as shown in Fig.7.1.2.4.2-4. In this method, one or more arbitrary OFDM symbols of a sub-frame may be used for mapping the SCH. However, since the same OFDM symbol position within a sub-frame and within a radio frame should be maintained, it is necessary to restrict MBMS transmission to sub-frames not affected by the SCH in the case that CPs of different lengths are used for the SCH and MBMS. Note that in all the three methods, if SCH transmission occurs multiple times in a radio frame, the information provided by the SCH may be distributed over multiple transmissions, or may be repeated.

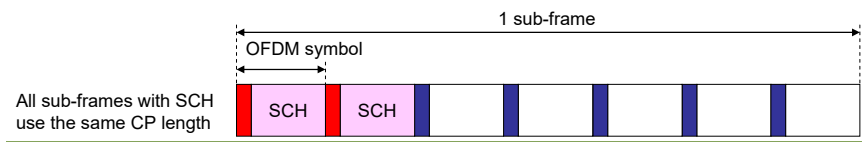


Figure 7.1.2.4.2-4 – Basic transmission timing of the downlink SCH within a sub-frame in the third method. Please note that this figure is for illustrative purposes only.

Additionally, the reference symbol detection method when there are sub-frames with different CP lengths within a radio frame, e.g., for multiplexing the MBMS channel, should be studied. There are two important issues to be studied.

- Restrict the time multiplexing of long-CP and short-CP sub-frames in order to allow performance improvements through averaging
- Modify the CP structure of the first OFDM symbol of a long-CP sub-frame in order to keep the same time-alignment of the first reference signal between short-CP and long-CP sub-frames (Figure 7.1.2.4.2-5)

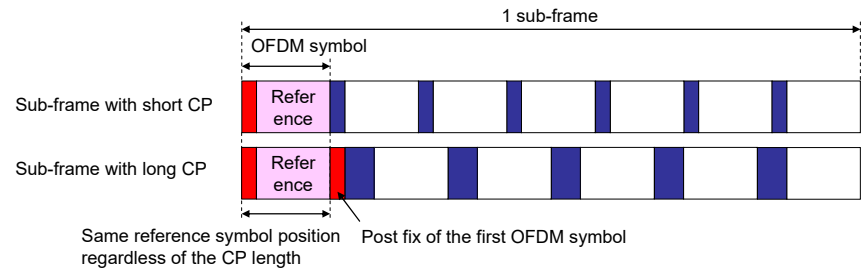


Figure 7.1.2.4.2-5 – Transmission timing of the first reference symbol within a sub-frame with long CP. Please note that this figure is for illustrative purposes only.

7.1.2.4.3 Structure in frequency

Given that whole mobility scenarios are not fully defined yet, the following assumptions are taken for evaluation during the SI phase:

- The center frequency of the center sub-carrier over the overall transmission band of each cell site is to be designed to satisfy the E-UTRA raster condition regardless of the overall transmission bandwidth of the cell site.
- The downlink SCH is transmitted only in the central part of the overall transmission band of the cell. As shown in Fig. 7.1.2.4.3-1, working assumption is to focus the study on a SCH structure based on the constant bandwidth of 1.25 MHz regardless of the overall transmission bandwidth of the cell, at least for initial cell search.
- The downlink BCH is also transmitted in the central part of the transmission bandwidth of the cell. In Fig. 7.1.2.4.3-2, the constant bandwidth of 1.25 MHz is used for the downlink BCH, regardless of the overall transmission bandwidth of the cell. Alternatively, the BCH may be transmitted over a 5-MHz frequency band to increase the frequency diversity effect when the overall transmission bandwidth is equal to or wider than 5 MHz. In the latter case, the UE may acquire the BCH bandwidth from the SCH to reduce the decoding complexity of the BCH, compared to the case when the UE tries to decode all the possible BCH bandwidths. Whether 1.25 MHz or 5 MHz is better as the BCH bandwidth should be investigated during the SI phase. Additionally, it should be investigated during the SI phase whether parts of the system information can be broadcast using a 1.25-MHz BCH and then, if necessary, the remainder of the system information is broadcast using a 5-MHz BCH.

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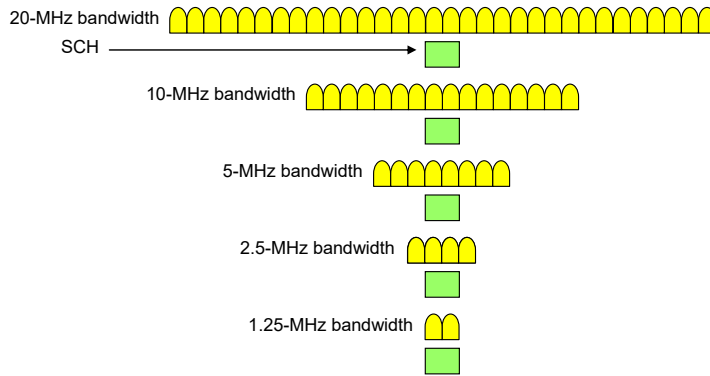
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- Regardless of the total transmission bandwidth capability of a Node B, a UE should be able to determine the cell ID using only the central portion of the bandwidth (i.e., the part of the bandwidth containing the SCH) in order to achieve very fast cell search.

Note that Figs. 7.1.2.4.3-1 and 7.1.2.4.3-2 are for illustration purposes only and the details of the SCH and BCH structure should be studied during SI_A.



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Figure 7.1.2.4.3-1 – Frequency allocation of the downlink SCH. Independent of the overall transmission bandwidth, the SCH is defined for 1.25 MHz and centered in the middle of the overall transmission bandwidth.

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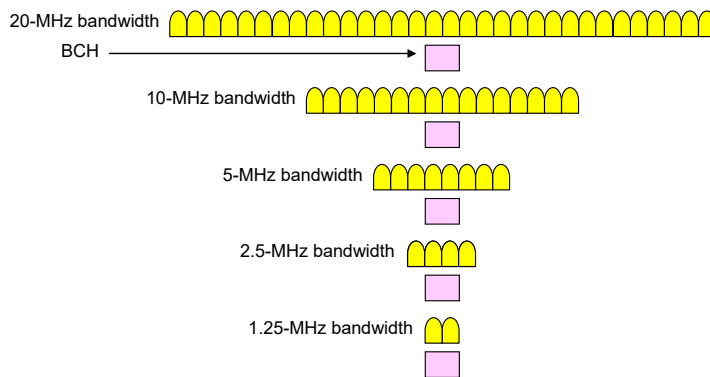


Figure 7.1.2.4.3-2 – Frequency allocation of the downlink BCH. Independent of the overall transmission bandwidth, the BCH is defined for 1.25 MHz and centered in the middle of the overall transmission bandwidth.

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Furthermore, allocation of a larger bandwidth for the SCH and BCH with repetition in the frequency domain and time-shifting of the block-wised BCH information in the case of a 20-MHz transmission bandwidth should be considered from the viewpoint of mobility support.

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A typical start up procedure would be that a UE first detects the central part of the spectrum regardless of the receiving bandwidth capability of the UE and the transmission bandwidth of the Node B and performs a cell search. Then, the UE

moves to the transmission bandwidth for actual communications assigned to it by the system. This procedure is illustrated in Fig. 7.1.2.4.3-3.

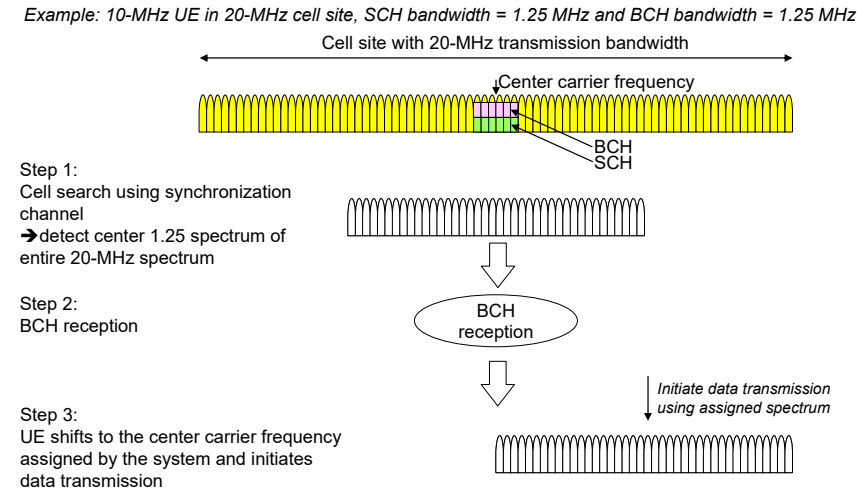


Figure 7.1.2.4.3-3 Principle of the cell search in Evolved UTRA.

7.1.2.4.4 Transmit diversity for SCH and BCH transmission

The SCH is the first physical channel for a UE to acquire. Thus, the SCH must be received without *a priori* knowledge of the number of transmitter antennas of the cell. Thus, transmit diversity methods that do not require knowledge of the number of transmit antennas can be considered for the SCH (e.g., time switched transmit diversity (TSTD), frequency switched transmit diversity (FSTD), and delay diversity including cyclic delay diversity (CDD)).

These diversity schemes can also be considered for the BCH in order to improve the packet error rate (PER) of the BCH. In addition, if the configuration of the transmitter antennas of the cell is provided outside the BCH, e.g., using the SCH or reference symbols, block code-based transmit diversity can be considered.

7.1.2.4.5 SCH signal structure

The two principal structures of the SCH might be identified, depending on whether the synchronization acquisition and the cell ID detection are obtained from the different SCH signals (hierarchical SCH, like in UTRA), or from the same SCH signal (non-hierarchical SCH).

Both SCH signal structures should be studied and compared.

7.2.2.4.5.1 Hierarchical SCH

In the hierarchical SCH, two or three signals are used for synchronisation acquisition and determining the cell ID and possibly other relevant information for the cell or network as mentioned in 7.1.2.4.1. A primary SCH, using the same OFDM waveform in all cells or a small set of OFDM waveforms with each cell using one of the OFDM waveforms, is used for SCH symbol timing and frequency acquisition. A secondary SCH, using a cell specific OFDM waveform, may be used for determining the cell group ID, full cell ID or other relevant information. If secondary SCH carries just cell group ID, not full cell ID, the cell specific common reference symbols can be used for determining the full cell ID. In case no secondary SCH is specified, the reference symbols specify the full cell ID.

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7.2.2.4.5.2 Non-hierarchical SCH

In the non-hierarchical SCH, the SCH consists of one or more cell-specific OFDM waveforms. A cell-specific OFDM waveform can be obtained by IDFT either of a complete cell-specific sequence or certain portion of a cell-specific sequence, where the sequence elements are used as the Fourier coefficients at the occupied sub-carrier frequencies. The occupied sub-carrier frequencies may be different on the different OFDM waveforms. The cell-specific sequence may indicate cell ID or cell group ID. Each OFDM waveform is preceded by a cyclic prefix. One or more cell-specific OFDM waveforms are characterized by an exactly or approximately symmetric (centrally symmetric or periodic) shape of their magnitudes at least in those parts of the SCH intended to be used both for the synchronization acquisition and the cell ID/cell group ID information transmission.

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7.1.2.5 Power control

Downlink power control for physical/L2-control signaling channel, at least tracking path loss and shadowing, should be investigated during the study item.

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7.1.2.6 Inter-cell interference mitigation

Three approaches to inter-cell interference mitigation are currently being considered.

- Inter-cell-interference randomization
- Inter-cell-interference cancellation
- Inter-cell-interference co-ordination/avoidance

In addition, the use of beam-forming antenna solutions at the base station is a general method that can also be seen as a means for downlink inter-cell-interference mitigation.

It should be noted that the different approaches could, at least to some extent, complement each other i.e. they are not necessarily mutually exclusive.

The possibility to perform inter-cell interference cancellation at the UE is considered irrespective of the interference mitigation scheme adopted at the transmitter. The radio interface definition should facilitate the acquisition of channel parameters of a limited number of (strongest) interfering cells (e.g. through orthogonal reference signals).

7.1.2.6.1 Inter-cell-interference randomization

Fundamentally, inter-cell-interference randomization aims at randomizing the interfering signal(s) and thus to allow for interference suppression at the UE in line with the processing gain.

Methods considered for inter-cell-interference randomization includes:

- *Cell-specific scrambling*, applying (pseudo) random scrambling after channel coding/interleaving
- *Cell-specific interleaving*, also known as *Interleaved Division Multiple Access* (IDMA)

A third means for randomization is to apply different kinds of frequency hopping.

With regards to inter-cell-interference randomization, cell-specific scrambling and cell-specific interleaving (IDMA) basically have the same performance (regarding IDMA for inter-cell interference cancellation, see below).

A pseudo-random method can be used to generate the cell-specific interleaver patterns for IDMA. The number of the available patterns (seeds) is determined by the length of interleaver. A UE can identify the interleaver pattern of the cell by checking its interleaver pattern ID. The seeds can be reused between "far-spaced" cells in a manner similar to that of frequency reuse in a cellular system.

7.1.2.6.2 Inter-cell-interference cancellation

Fundamentally, inter-cell-interference cancellation aims at interference suppression at the UE beyond what can be achieved by just exploiting the processing gain.

Two methods have been discussed

- Spatial suppression by means of multiple antennas at the UE. It should be noted that the availability of multiple UE antennas is an assumption for E-UTRA.
- Interference cancellation based on detection/subtraction of the inter-cell interference. One example is the application of cell-specific interleaving (IDMA) to enable inter-cell-interference cancellation.

The IDMA based inter-cell-interference cancellation scheme would imply the following requirements on the system:

1. RB allocation: The RBs accommodating one code block of a UE in the interfered cell should also accommodate, and only accommodate, a code block of a UE in the interfering cell. In other words, the “interfered code block” and “interfering code block” should be accommodated in the same set of RBs.
2. Synchronization: Inter-NodeB synchronization is required.
3. Intra-cell signalling: A UE needs to be signalled whether it can perform a cancellation to the received ICI. When IDMA is used, the interleaver pattern ID also needs to be signalled to the UE.
4. Inter-cell signalling: Interfering signal configurations (e.g. interleaver pattern ID, modulation scheme, FEC scheme and coding rate) should also be signalled to the UE. To cancel the inter-NodeB interference, the signalling of interfering signal configurations can be realized by detecting the interfering control channel at the UE. To cancel the inter-sector interference, the NodeB can straightforwardly signal the interfering signal configurations to the UE via its own controlling channel.

7.1.2.6.3 Inter-cell-interference co-ordination/avoidance

The common theme of inter-cell-interference co-ordination/avoidance is to apply restrictions to the downlink resource management (configuration for the common channels and scheduling for the non common channels) in a coordinated way between cells. These restrictions can be in the form of restrictions to what time/frequency resources are available to the resource manager or restrictions on the transmit power that can be applied to certain time/frequency resources. [Such restrictions in a cell will provide the possibility for improvement in SIR, and cell-edge data-rates/coverage, on the corresponding time/frequency resources in a neighbour cell.](#)

Different assumptions can be made regarding UE measurements/reporting needed to support downlink interference co-ordination:

- Alternative #1:
No additional UE measurement and reporting is needed, in addition to CQI reports anyway needed to support channel-dependent scheduling and link adaptation
- Alternative #2:
Additional UE measurement and reporting of average path loss (incl. shadowing) to current and ~~neighbour~~neighbour cells. Reporting rate: In the order of once every 100 ms.
- Alternative #3:
In addition to the measurements/reports of alternative #2, additional measurement and reporting of average interference for the frequency reuse sets. Reporting rate: In the order of once every 100 ms.

Inter-cell interference co-ordination will require certain inter-communication between different network nodes in order to set and reconfigure the above mentioned scheduler restrictions. Two cases ~~is~~are considered:

- Static interference co-ordination
Reconfiguration of the restrictions is done on a time scale corresponding to days. The inter-node communication is very limited (set up of restrictions), basically with a rate of in the order of days.
- Semi-static interference co-ordination
Reconfiguration of the restrictions is done on a time scale corresponding to seconds or longer. Inter-node communication corresponds to information needed to decide on reconfiguration of the scheduler restrictions (examples of communicated information: traffic-distribution within the different cells, downlink interference contribution from cell A to cell B, etc.) as well as the actual reconfiguration decisions. Signaling rate in the order of tens of seconds to minutes.

7.1.2.7 Inter-Node B Synchronization

7.1.3 Physical layer measurements

7.1.3.1 UE measurements

7.1.3.1.1 Measurements for Scheduling

7.1.3.1.1.1 Channel Quality Measurements

The UE should be able to measure and report to the Node B the channel quality of one resource block or a group of resource block, see Section 7.1.3.1.1.1.1 in form of a CQI. In order to allow for efficient trade-off between UL signaling overhead and link-adaptation/scheduling performance taking varying channel-conditions and type of scheduling into account, the time granularity of the CQI reporting should be adjustable in terms of sub-frame units (periodic or triggered) and set on a per UE or per UE-group basis. In addition, the amount of overhead should be considered when comparing different CQI reporting schemes. .

7.1.3.1.1.1.1 Channel Quality Indicator

The frequency dimension of OFDM symbols can be organized into an integer number of CQI bands across all carrier bandwidth modes with each CQI band bandwidth corresponding to x (e.g. $x=25$ or 50) number of consecutive sub-carriers. The granularity of the CQI band bandwidth should be multiples of the minimum resource block bandwidth.

Channel quality indicator (CQI) feedback from UE which indicates the downlink channel quality can be used at Node B at least for the following purposes:

- Time/frequency selective scheduling.
- Selection of modulation and coding scheme.
- Interference management,
- Transmission power control for physical channels, e.g., physical/L2-control signaling channels.

Various techniques or combinations thereof can be considered for reducing CQI feedback which include (as examples) the following:

- Only feedback information from the top M strongest CQI bands
- Differential feedback information in time or frequency
- Bitmap techniques indicating which bands reflect a reported CQI value
- Hierarchical Tree structure based approaches
- Using a set of (orthogonal) functions to approximate frequency selective fading profile (e.g. DCT)

7.1.3.1.1.2 Measurements for Interference Coordination/Management

Channel quality measurements defined in section 7.1.3.1.1.1 and some measurements defined in section 7.1.3.1.2 can be used for interference coordination/management purpose. Additional measurements for interference coordination/avoidance are considered in sections 7.1.2.6.3 and 9.1.2.7.1 for DL and UL respectively.

7.1.3.1.2 Measurements for Mobility

In order to support efficient mobility in EUTRAN, the UEs are required to identify and measure the relevant measurement quantities [FFS] of neighbour cells and the serving cell. Such measurements for mobility are needed in the following mobility functions:

- 1) PLMN selection
 - a. Detecting available PLMNs and high quality PLMNs
- 2) Cell selection and cell reselection
 - a. Detecting suitable cells (i.e., "S-criteria or out-of-range")

- b. Determining the most suitable cell for connection, i.e. performing evaluation for cell reselection
- 3) Handover decision
 - a. Intra frequency handover
 - b. Inter frequency handover
 - c. Inter RAT handover (GERAN, UTRAN)
 - d. Measurement gap control (FFS)

7.1.3.1.2.1 Intra frequency neighbour measurements

Neighbour cell measurements performed by the UE are named intra-frequency measurements when the UE can carry out the measurements without re-tuning its receiver. This corresponds to the case when the current and target cell operates on the same carrier frequency and

- the UE maximum bandwidth capability is equal or larger than the network system bandwidth, or
- the UE maximum bandwidth capability is smaller than the network system bandwidth, but the UE is currently “camping” within a band so that the common channels of the target cell as well as the sub-carriers allocated to the UE on the DL shared channel are within the UE receiving bandwidth.

Note that the exact definition of the common channels that are needed for the neighbour measurements as well as the meaning of “camping” are not yet fully agreed upon.

7.1.3.1.2.2 Inter frequency neighbour measurements

Neighbour cell measurements are considered inter-frequency measurements when the UE needs to re-tune its receiver in order to carry out the measurements. This corresponds to the cases when

- the neighbour cell is operating on a different carrier frequency than the current cell, or
- the neighbour cell is operating on the same carrier frequency as the current cell, but the UE maximum bandwidth capability is smaller than the network system bandwidth and the UE is currently “camping” within a band so that the common channels of the target cell are outside the UE receiving bandwidth. Note that depending on the exact structure for the common channels needed for neighbour measurements, this scenario may not happen.

In case of inter-frequency measurements, the network needs to be able to provide UL/DL idle periods for the UE to perform necessary neighbour measurements.

7.1.3.1.2.3 Inter RAT measurements

Neighbour measurements are considered inter-RAT measurements when UE needs to measure other radio access technology cells. For these kinds of measurements, the network needs to be able to provide UL/DL idle periods.

7.1.3.1.2.4 Measurement gap control

In case the UE needs UL/DL idle periods for making neighbour measurements or inter-RAT measurements, the network needs provide enough idle periods for the UE to perform the requested measurements. Such idle periods are created by the scheduler, i.e. compressed mode is assumed not needed. In order to optimise the network, some additional measurements may be used by the network for triggering the generation of UL/DL periods. This is FFS.

7.1.3.2 E-UTRAN measurements

7.2 MC-WCDMA (FDD)

7.2.1 High level principles

This structure prioritizes spectrum compatibility, that is ability for legacy UE and evolved UTRA UEs to co-exist in the same spectrum allocation. The baseline structure, numerology and procedures should be the same as those defined for UTRA-FDD HS-DSCH; in particular:

- Frequency re-use 1
- Node-B scheduling
- Adaptive modulation and coding
- Fast layer 2 re-transmissions
- Fast cell switching without data loss

should be supported. This should be achieved without tight inter-site synchronisation.

The following additions to the baseline multiple access structure should be considered:

- Enhanced MAC/RLC in support of simultaneous transmission over multiple carriers (up to 20 MHz)
- Support for MIMO for HS-DSCH operation.
- Support for simultaneous reception of HS-DSCH and multicast data transmitted according to the simulcast structure and procedures described in clause [X] should be evaluated.
- Added support for 0.96 Mcps and possibly 1.92 Mcps numerology.
- Enhanced downlink control structure and procedures in support of HS-DSCH and E-DCH operation with variable symmetric and asymmetric bandwidth allocations.
- Support for higher order modulation such as 64 QAM.
- Reduced downlink HARQ delay budget.

The system operation should rely on the definition of new demodulation performance requirements as follows:

- Enhanced HS-PDSCH performance requirements relying on:
 - Enhanced reference equalizer such as frequency domain equalizer with decision feedback combined with multi-antenna receive diversity in the UE.
 - Intra and Inter cell interference reduction in the UE.
- Enhanced S-CCPCH performance requirements in support of MBMS relying on:
 - Dual antenna receive diversity in the UE.

7.2.2 Basic Transmission Scheme

This section goes over the specifics for a MC-WCDMA operation on the DL. Section 7.2.2.2 introduces operation over a 1.25MHz bandwidth by means of a low chip rate version of UTRA FDD (WCDMA LCR in the sequel). WCDMA LCR operation is based on direct sequence spreading over 1.25MHz.

The concepts presented are valid for multi-carrier operation based on the 5MHz system (UTRA FDD) as well as the 1.25MHz system (WCDMA LCR) or a 5MHz/1.25MHz hybrid multi-carrier system.

7.2.2.1 Definitions

N: maximum number of DL carriers that a UE may receive at a given time. The notion of “carrier assignment” is implicit with this concept, i.e., the E-UTRAN shall notify the UE that it may receive data on up to N carriers simultaneously.

M: maximum number of UL carriers that a UE may transmit at a given time. Also, the notion of “carrier assignment” is implicit with this concept, i.e., the E-UTRAN shall notify the UE that it may transmit data on up to M carriers simultaneously.

Paired Carriers: carrier frequencies such that for each DL carrier there is an associated UL carrier. The PHY channel timing relationships for paired carriers are the same as those for the currently defined single carrier UMTS system.

Unpaired Carriers: carrier frequencies that do not have an associated DL carrier (in case of $M > N$) or do not have an associated UL carrier (in case of $N > M$). The timing of PHY channels of unpaired carriers will be associated with the timing of some paired carriers. Details on this will be provided in the body of this document.

Anchor Carrier: carrier within a cell that contains full R99, R5 or R6 capability, i.e., transmission of SCH, P-CCPCH, S-CCPCH... and supporting reception of UE random access by way of the PRACH. For the downlink, the anchor carrier in a cell constitutes the timing reference for all the carriers in that cell i.e., time synchronization within the carriers in a cell is assumed as stated section 7.2.2.2.

7.2.2.2 WCDMA LCR system numerology

Table 7.2.2.2-1 presents the numerology for the WCDMA LCR system.

Table 7.2.2.2-1. WCDMA LCR system numerology

Parameter	Value
Carrier spacing	1.25MHz
Chip rate	960 kcps
Slot duration	0.67ms: 640 chips
Max SF	128
R5/R6 TTIs	2ms: 3 slots 10ms: 15 slots

The chip rate for the WCDMA LCR system comes from a direct translation to a 1.25MHz carrier spacing of the relationship between the carrier spacing and the chip rate for the UTRA FDD, i.e., 3.84Mcps is to 5MHz the same as 960kcps is to 1.25MHz. Therefore, the same pulse shaping filter taps are assumed for the 1.25MHz system, with the difference that the sample duration is 4 times longer in the 1.25MHz system.

The slot duration for the 1.25MHz system corresponds to the UTRA slot duration of 0.67ms. Therefore, since the “chips” of the 1.25MHz system are 4 times longer, the number of chips in a slot is $2560/4=640$. The number $640=128 \times 5$, and therefore the maximum spreading factor is 128, for which there will be 5 Walsh symbols per slot. For this slot duration, the TTI duration in slots corresponding to the R5 and R6 channels remains the same i.e., 2ms and 10ms, as in UTRA FDD.

7.2.2.3 Assumptions for MC-WCDMA operation in DL

Only the HSDPA channels are eligible to be configured in a multi-carrier fashion i.e., a given UE will receive information from one or more than one carrier.

The time reference for cells connected to the same Node B is assumed to be common across all carriers. Therefore, the DL timing reference i.e., timing of the P-CCPCH or SCH is the same for all carriers in a given cell.

The timing of the PHY channels for *paired carriers* shall be no different than for a single carrier system where the timing of all the DL channels is referenced to the timing of the P-CCPCH or SCH.

The timing of the PHY channels for *unpaired carriers* is explicitly covered in this Technical Report.

Multi-Carrier transmission characteristics:

- One cell is the serving cell for all carriers supported by a given UE.
- [Multi-carrier] split of the user data buffer is at the Node-B.
- Node-B can do individual carrier scheduling or joint carrier scheduling.
- HARQ PHY re-transmissions on DL takes place at the same carrier as for the first transmission.

Figure 7.2.2.3-1 is a block diagram depicting multi-carrier operation. Each of the colours represents a different DL carrier. Transmission by the serving cell is represented by solid lines, whereas transmissions by other cells are represented by dashed lines. Note that the PHY channels in squared brackets are just transmitted if associated uplink carrier is configured.

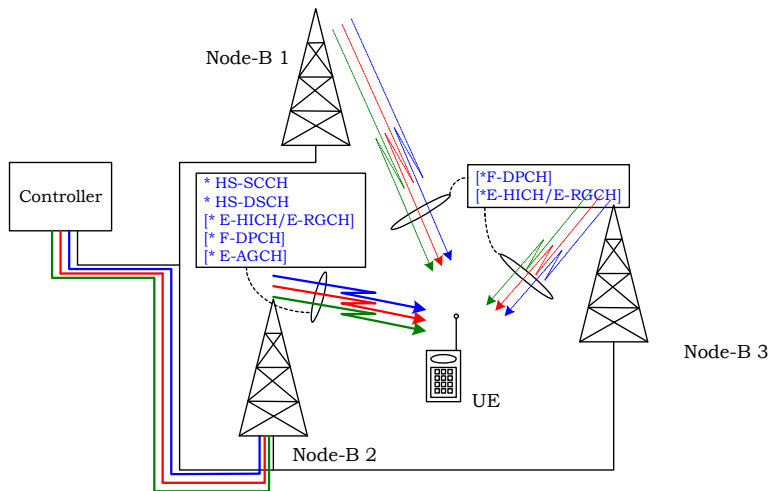


Figure 7.2.2.3-1. Block diagram for multi-carrier operation

7.2.2.4 DL Single-carrier PHY Channels

The DL channels that could be transmitted on one carrier only are listed below.

- SCH: Primary and Secondary Synchronization channels – allowing UE initial system acquisition.
- P-CCPCH: Primary Common Control Physical channel carrying the system information i.e. BCH: Broadcast transport channel.
- S-CCPCH: Secondary Common Control Physical channel carrying the Paging (PCH) and the Forward Access Channel (FACH) transport channels. If there is interest in increased data transmission capabilities over FACH, transmission of the S-CCPCH could take place on more than one carrier in a cell.
 - PICH: Paging Indicator Channel if S-CCPCH carrying the PCH is transmitted over a single carrier.
 - MICH: MBMS Indicator Channel if S-CCPCH carrying the MBMS contents is transmitted over a single carrier.
- DPCH: for e.g., real time services.

7.2.2.5 DL Multi-Carrier PHY Channels

The set of downlink PHY multi-carrier channels is the following:

- Table 7.2.2.5-1 shows the data-payload channels:

Table 7.2.2.5-1. Data-payload Multi-carrier DL PHY channels

Channel	Num carriers
HS-PDSCH	N

- Table 7.2.2.5-1 shows the control/supporting channels:

Table 7.2.2.5-1. Control/supporting Multi-carrier DL PHY channels

Channel	Num required channels	Rationale
HS-SCCH	N	The number of required channels, N, should be multiplied by the number of simultaneous users that may be supported per slot, per carrier
(F-)DPCH	M	UL Power Control commands for M uplink carriers
E-HICH	M	ACK/NAKs for M E-DPCHs
E-RGCH	M	Relative Grants for M E-DPCHs
E-AGCH	M or 1	Absolute Grants for M E-DPCHs

The Absolute Grant messages for a multi-carrier UE with M uplink carriers may be transmitted on M independent E-AGCH PHY channels (in same or different carriers) or could be transmitted on a single PHY channel at a particular DL carrier. In that case, the E-RNTI identifier would require the additional notion of “carrier” on top of the notion of UE identity. Therefore, a UE could have more than one associated E-RNTI e.g., one for each UL carrier that is allowed to use.

7.2.2.5.1 N/M Asymmetry considerations

The following observations can be made for the different relative values of N and M.

- N=M:** All the DL carriers have an associated UL carrier and vice-versa. PHY procedures for this case (i.e., Power Control, synchronization, HS-DSCH and E-DCH related procedures...) are no different than those for the single carrier case.
- N>M:** Just the M paired carriers require (F-)DPCH, E-HICH/E-RGCH and E-AGCH (in case of M AGCH channels used). There are (N-M) downlink unpaired carriers carrying the HS-PDSCH and its associated HS-SCCHs.
- N<M:** There are (M-N) uplink unpaired carriers. Therefore, the following will be required:
 - (M-N) additional (F-)DPCHs for UL power control of the (M-N) uplink unpaired carriers.
 - (M-N) additional E-HICH/E-RGCH channel pairs using (M-N)x2 additional signatures for PHY HARQ ACK/NACK and RG indications of the (M-N) uplink unpaired carriers.

- (M-N) additional E-AGCH channels for transmission of the absolute grants of the (M-N) uplink unpaired carriers if M E-AGCHs are transmitted for a UE with M uplink carriers. If a single E-AGCH is used for the absolute grants of a UE in all the UL carriers, no additional E-AGCHs are needed.

The (M-N) sets of additional channels ((F-)DPCH, E-HICH/E-RGCH and optionally E-AGCH) are related to E-DCH transmissions on the UL. Therefore, the cells in the UE's E-DCH Active Set of each carrier shall transmit to the UE the supporting E-DCH feedback information and the RL TPC commands. For cells belonging to the same Node-B, the transmission of these channels shall take place at the same carriers. It may also be desired, for implementation reasons, that the carriers for transmission of these channels are the same for different Node-Bs.

Note that multiple F-DPCHs on a given carrier may be orthogonally time multiplexed within the same channelization code by using different timing offsets (multiples of 256 chips). Therefore, the additional F-DPCHs may be time multiplexed within a set of DL carriers. Alternatively, different channelization codes may be used for the additional F-DPCHs with timing same or different than that of the paired F-DPCH.

Clearly, allocation of F-DPCHs is more advantageous than allocation of DPCHs as multiplexing in time sharing the same channelization code is possible with the former.

7.2.3 Physical Layer Procedures

7.2.3.1 DL PHY channels timing considerations

As stated before, the timing of PHY channels for symmetric, i.e., $N = M$, multi-carrier configurations is such that each carrier complies with the timing requirements set forth in 25.211.

This section covers the timing specifics of DL PHY channels for asymmetric, i.e., $N \neq M$ multi-carrier configurations.

In the $N > M$ case, there are (N-M) downlink unpaired carriers. The timing of the DL channels in these carriers (HS-PDSCH and HS-SCCH) is well defined since for the DL, the timing of all the PHY channels is referenced to the nominal timing of the P-CCPCH or SCH of the anchor carrier.

In the $N < M$ case, there are (M-N) uplink unpaired carriers. Also, there are (M-N) sets of channels ((F-)DPCH, E-HICH/E-RGCH and possibly E-AGCH) that need to be allocated within the N downlink carriers. The timing of E-HICH is indirectly related to the timing of the associated (F-)DPCH. The timing of the E-RGCH for the serving cell coincides with the timing of the E-HICH. Whereas, the timing of the E-RGCH from a non-serving cell as well as the timing of the E-AGCH is absolute with respect to the nominal timing (2 slots after). In addition, as noted before, the E-AGCH may be transmitted on a single carrier. Therefore, the (M-N) additional (F-)DPCHs (on top of the N ones corresponding to the paired carriers) will have a particular timing multiple of 256 chips which will constitute the indirect reference for the E-HICH and the E-RGCH from the serving cell.

Note that multiple F-DPCHs on a given carrier may be orthogonally time multiplexed within the same channelization code by using different timing offsets (multiples of 256 chips). Therefore, the additional F-DPCHs may be time multiplexed within a set of DL carriers. Alternatively, different channelization codes may be used for the additional F-DPCHs with timing same or different than that of the paired F-DPCH.

7.2.3.2 Synchronization Procedures: Cell Search

7.2.3.2.1 "Cold" Acquisition

The "cold acquisition" denotes the system acquisition from UE power up. Therefore, it is the acquisition of the first carrier (anchor carrier).

There are no changes in the procedure described in 25.214, however just a subset of carriers (the smallest subset being the single anchor carrier) will carry the P-SCH/S-SCH and the P-CCPCH and therefore will enable the UE to perform the three steps for system acquisition.

7.2.3.2.2 "Warm" Acquisition

The "warm acquisition" denotes the addition of DL carriers.

If different carriers from the same cell share a common timing reference (as assumed in section 7.2.2.2), there is no need for steps 1 and 2 in the system acquisition process described in 25.214 (related to the acquisition of the slot and frame timing as well as the identification of the scrambling code group to which the cell belongs, through acquisition of P-SCH and identification of S-SCH). Step 3 (last step) in the system acquisition procedure described in 25.214 may also be avoided if different carriers from different cells use the same scrambling code.

Therefore, the two constraints:

- Common timing reference for all carriers from same cell, and
- Common scrambling code for all carriers from same cell,

bring notorious advantages on the addition of DL carriers procedure and therefore shall be required.

If the common timing reference for carriers from same cell was optional. A signalling message could be defined with the objective of indicating whether or not each of the DL carriers share the same timing as the anchor carrier.

In turn, if the use of common scrambling code for carriers from same cell was optional. The E-UTRAN would have to indicate through signalling (e.g., P-CCPCH or S-CCPCH) the scrambling code used by carriers other than the anchor carrier. This approach would add unnecessary overhead on the DL and is not desired.

7.2.3.3 Synchronization Procedures: Synchronization of Dedicated channels

7.2.3.3.1 Procedure A

This section covers Procedure A step by step identifying the points that could be different for the addition of a new carrier.

Procedure A step “b” in 25.214 currently specifies that the initial transmit power for the DL DPCCH or F-DPCH is set by higher layers. This transmit power could be chosen to be the same as that for one of the established carriers.

The DL chip and frame synchronization described in step “c” may be simplified for the assumption of common timing from different carriers.

Step “d” specifies when the UE may start transmitting. Currently, higher layers need to consider the DL physical channel established and activation time (if provided) reached. After that, transmission of DPCCH start at an initial transmit power set by higher layers. This initial DPCCH power may also be the same as one of the other active carrier’s DPCCH. The power control preamble, in this case, may also be reduced to speed up the synchronization.

7.2.3.3.2 Procedure B

Synchronization Procedure B does not involve the UE as it governs the addition of radio links to the existing radio link sets between the UE and E-UTRAN. Therefore, it would not require any change to specifically support multi-carrier operation.

7.2.3.4 Power Control: DL PC

Section 9.3.2.4 covers the UL multi-carrier channels and therefore the DPCCHs carrying the power control commands for the DL (to control the transmission power of the (F-)DPCHs and HS-SCCHs).

For each of the N/M relative values:

- **M=N**: each UL carrier has its associated DL carrier and vice-versa. Therefore, the M uplink DPCCHs will power control the M downlink (F-)DPCHs, and optionally the HS-SCCHs and the DL E-channels.
- **M>N**: there are N uplink DPCCHs meaningful for DL power control. Those are the N paired carriers that power control the downlink (F-)DPCHs and optionally HS-SCCHs in the N downlink carriers.
- **M<N**: the DPCCHs in the M paired carriers will power control the M downlink (F-)DPCHs. Power control of the HS-SCCHs in the (N-M) downlink unpaired carriers may be based on CQI reports for each of the carriers by the UE.

7.2.3.5 HS-DSCH Related Procedures

Transmission of HSDPA related channels is covered in section 7.2.2.5 for the DL (i.e., HS-PDSCH and HS-SCCH) and section 9.3.2.4 for the UL (i.e., HS-DPCCH).

For each of the possible N/M relative values:

- **N=M**: each DL carrier has its associated UL carrier and vice-versa. Therefore, the N downlink HS-PDSCHs/HS-SCCHs will be fed back by the corresponding N uplink HS-DPCCHs.
- **N>M**: the HS-PDSCHs/HS-SCCHs in the M paired carriers will be fed back by the corresponding M uplink paired HS-DPCCHs. In addition, the UE further conveys CQI and ACK/NACK commands for the (N-M) downlink unpaired carriers for HARQ operation and channel feedback of the HS-PDSCH of those carriers. How that additional information is conveyed is covered in section 9.3.2.4.1.
- **N<M**: the HS-PDSCHs in the N paired carriers will be fed back by their corresponding HS-DPCCHs in the paired carriers.

7.2.3.5.1 HS-PDSCH Retransmission on Multi-Carrier system

Operation in the multi-carrier system shall guarantee PHY HARQ retransmissions on the carrier that was used for the first transmission.

7.2.4 Physical layer measurements

7.2.4.1 UE measurements

The UE measurements for the MC-WCDMA based proposal are the same as those defined in section 5.1 of 25.215.

7.2.4.2 Measurements support for mobility

For the MC-WCDMA based proposal, measurements and procedures to support mobility towards UTRA and GSM RAT do not differ from currently specified procedures.

Likewise, measurements and procedures to support mobility towards and within E-UTRA do not differ from currently specified procedures.

Measurements periods to support inter-frequency and inter-RAT handover are provided by compressed mode operation and/or new DTX/DRX procedures for the UE.

7.3 MC-TD-SCDMA (TDD)

7.3.1 Basic transmission scheme

The frame and sub-frame structure of 3GPP 1.28Mcps LCR TDD option are shown in the Figure 7.3.1-1 and 7.3.1-2 ^[7]. The Figure 7.3.1-3 is the frame structure of Multi-carrier TD-SCDMA(MC TD-SCDMA). As shown in Figure 7.3.1-3, for downlink frame structure, a carrier with broad bandwidth can be divided into several sub-carriers of narrower bandwidth, and adjacent sub-carriers do not overlap with each other. Multi-carrier TD-SCDMA can meet different needs in the DL resource allocation and make full use of the resources, by using FDMA, TDMA and CDMA modes altogether.

For the DL multiple access, the bandwidth of each downlink sub-carrier will be allocated as 1.6 MHz.

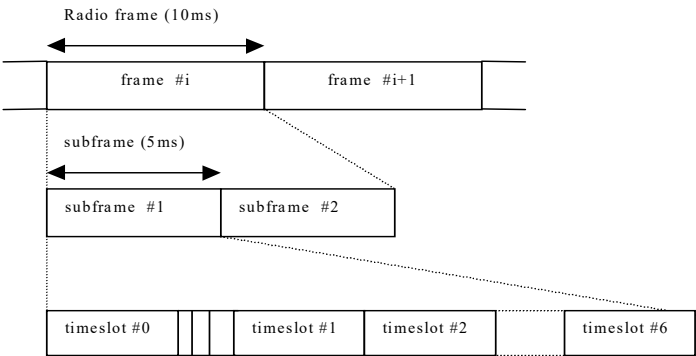


Figure 7.3.1-1: Physical channel signal format for 1.28Mcps TDD option

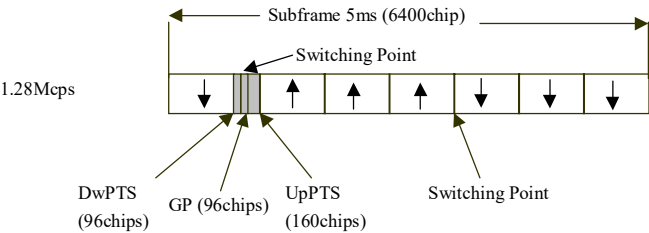


Figure 7.3.1-2: Structure of the sub-frame for 1.28Mcps TDD option

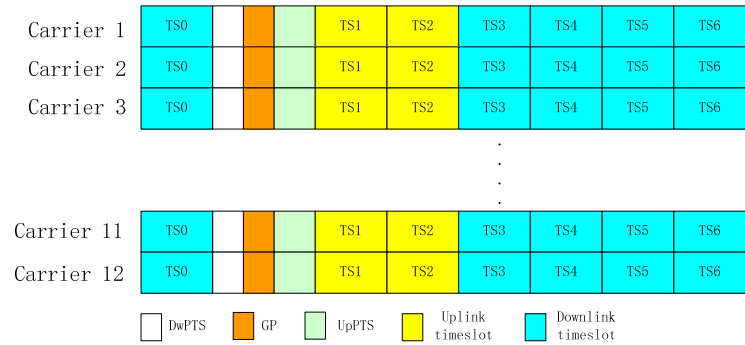


Figure 7.3.1-3: MC TD-SCDMA frame structure based on LCR TDD

The sub-carrier number of DL and UL in the different bandwidths are given in Table 7.3.1-1.

Table 7.3.1-1 the number of UL and DL sub-carriers according to different bandwidths

Bandwidth	1.6MHz	5MHz	10MHz	15MHz	20MHz
DL sub-carrier number	1	3	6	9	12
UL sub-carrier number	1	3	6	9	12

MC TD-SCDMA should have similar structure as LCR TDD (Figure 7.3.1-1), i.e. three layered structure: radio frame, sub-frame and time slot. The number and position of traffic and special time slots are also the same, aligned with current system. The TTI is 0.675ms, the same size as the period of a timeslot.

For general services, MC TD-SCDMA can use the same number of switching points as shown in Figure 7.3.1-2.

More Switching points can be added in the 5ms sub-frame of MC TD-SCDMA to meet special requirements as shortened latency. For example, one pair of switching points can be added as in Figure 7.3.1-4 to meet the 5ms unidirectional user plane latency requirement in the LTE. In Figure 7.3.1-4, TS0, TS2, TS3, TS5 and TS6 are downlink timeslots, while TS1, TS4 act as uplink. One pair of switching points is added to reduce latency.

In Figure 7.3.1-4, TS4 is composed of two parts: the guard period GP and T4. The functionality of GP is the same as special time slot GP, which acts as a protection between downlink and uplink slots. T4 is a part which used to transmit uplink data. To maintain the alignment with LCR TDD system, the length of TS4 remains 0.675ms. The number of switching points can be further increased on the basis of Figure 7.3.1-4 to fulfil even more stringent needs for lower latency.

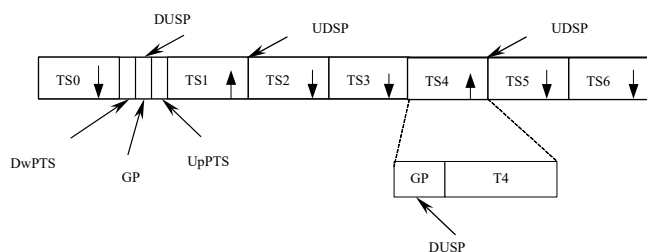


Figure 7.3.1-4 Switching points added in a sub-frame

7.3.1.1 Modulation scheme

The downlink scheme of MC TD-SCDMA supports QPSK, 16QAM and 64QAM modulation schemes.

7.3.1.2 Multiplexing including pilot structure

7.3.1.3 Channel Coding and physical channel mapping

Convolution coding and Turbo coding can be considered for MC TD-SCDMA. Each coding scheme has its own characteristic.

7.3.1.4 MIMO and beam-forming

There are two main multiple antenna technologies, namely Beam-forming and MIMO. MC TD-SCDMA combines these two technologies according to different application environment and channel characteristics.

The baseline antenna configuration for downlink MIMO is to deploy two transmit antennas at the Cell site, and two receive antennas at the UE. The possibility for more transmit antennas should also be considered.

The antenna configuration for downlink beam-forming is to use from four to eight transmit antennas at the Cell site, and one or two receive antennas at the UE.

7.3.2 Physical layer procedure

7.3.2.1 Scheduling

For DL MC TD-SCDMA, frequency diversity, time diversity and space diversity should be considered.

7.3.2.1 Link adaptation

Using AMC to adjust the modulation and coding rate, adaptive link technologies improve the performance of the system.

7.3.2.3 HARQ

Incremental Redundancy (IR) should be used for downlink HARQ. Note that Chase combining is a special case of IR.

7.3.2.4 Cell search

7.3.2.5 Power control

The open-loop and close-loop power control are supported against deep fading, eliminating near-far effect, and fighting multi-user interference.

7.3.3 Physical layer measurements

7.3.3.1 UE measurements

7.3.3.2 Measurements support for mobility

8 Evaluation of techniques for evolved UTRA DL

8.1 Performance evaluation

Evaluation components such as spectral efficiency and throughput requirements are given in [44] for characterizing performance of a EUTRA MA proposal and determining whether it meets relative improvement requirements over Release 6 UTRA. The evaluation should at least be performed for a 10MHz bandwidth mode at 2.0GHz and a 1.25MHz bandwidth mode at 900MHz as given in Table 8.1.1-1. It is highly desirable to eventually show 20MHz performance results as well.

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8.1.1 Traffic outage and latency requirements

Outage requirements for the different traffic models are needed for alignment. System loading is limited by the outage limit for each traffic type. Outage should also be conditioned on signaling reliability. That is, signaling error types that would result in extra packet loss or retransmissions that would significantly affect performance should be modeled or reported. Note that user packet call throughput by definition [22], [33] includes the effects of packet scheduling delay. See Annex A.4 for examples of evaluation approaches.

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Table 8.1.1-1 – Traffic Outage and Latency requirements for determining maximum load

Traffic Type	Outage Limit and Definition
HTTP – Web Browsing with TCP	2% outage based on user packet call throughput < P P=128Kbps for BW>2.5MHz otherwise P=32Kbps
FTP – with TCP	2% outage based on user packet call throughput < Q Q=128Kbps for BW>2.5MHz otherwise Q=32Kbps
VoIP	2% outage based on user having < 98% of its speech frames delivered successfully within [40] ms (air interface delay). Consecutive speech frames erased < [0.05]% of time
S Kbps Streaming Video S=128 for BW >2.5MHz otherwise 64	2% outage based on user having > 2% dropped packets
Video Conferencing	Audio same as VoIP; Video same as Streaming

8.1.2 Evaluation against reference

Note: absolute results shown in the respective sections should not be compared as the set of assumptions used to derive these respective results may differ.

This section provides initial results of different E-UTRA downlink proposals, comparing with the baseline reference case defined in [x]:

- WCDMA Release-6
- 1 Transmit antenna at the Node-B
- 2 Receive antennas at the UE
- Rake receiver
- 5 MHz transmission bandwidth

Results are normalized to bit per second per Hertz.

8.1.2.1 Evaluation for MC-WCDMA based evolved UTRA DL

The initial evaluation results presented in Table 8.1.2.1-1 are based on full buffer traffic models and proportional fair scheduler. For MC-WCDMA based E-UTRA, the numbers represent the performance assuming receive diversity and linear MMSE equalization in the UE. The downlink overhead is assumed to be 25% for both sets of results.

Table 8.1.2.1-1: Full buffer – 10 users per sector

Case	Speed [km/h]	Reference WCDMA Type I [b/s/Hz]	MC-WCDMA Eq1 + 2 RxDiv [b/s/Hz]	% w.r.t Reference
1	3	0.988	1.512	+ 53%
2	30	0.664	1.066	+ 61%
3	3	0.922	1.370	+ 49%
4	3	0.938	1.456	+ 55%

Additional benefits from MIMO operation is for further study.

8.1.2.2 Evaluation for OFDMA based evolved UTRA DL

The initial evaluation results presented in Tables 8.1.2.2-1, 8.1.2.2-2 and 8.1.2.2-3 are based on full buffer traffic models and proportional fair scheduler. It is assumed that the scheduler is able to independently allocate individual sub-bands to different UEs at the same time. Further, it is assumed that the UE reports full CQI for all downlink sub-bands.

The downlink overhead for OFDM results in Tables 8.1.2.2-1, 8.1.2.2-2 and 8.1.2.2-3 is assumed to be 25%, 29% and 20% respectively.

Table 8.1.2.2-1: Full buffer – Set 1 – 10 users per sector

Case	Speed [km/h]	Reference WCDMA Type I [b/s/Hz]	OFDM 2 ms TTI 1125 KHz sub-bands [b/s/Hz]	OFDM 0.5 ms TTI 1125 KHz sub-bands [b/s/Hz]	% w.r.t Reference
1	3	0.988	1.616	1.560	+ 64% (2.0 ms) + 58% (0.5 ms)
2	30	0.664	1.070	1.260	+ 61% (2.0 ms) + 90% (0.5 ms)
3	3	0.922	1.526	-	+ 66%
4	3	0.938	1.590	-	+ 70%

Table 8.1.2.2-2: Full buffer – Set 2 – 10 users per sector

Case	Speed [km/h]	Reference WCDMA Type I [b/s/Hz]	OFDM 0.5 ms TTI 375 KHz sub-bands [b/s/Hz]	% w.r.t Reference
1	3	0.988	1.840	+ 86%
2	30	0.664	1.510	+ 127%
3	3	0.922	1.620	+ 76%

Table 8.1.2.2 -3: Full buffer – Set 3 – 10 users per sector

Case	Speed (kph)	Reference WCDMA Type I (bps/Hz)	OFDM 0.5 ms TTI 563 KHz sub-bands (bps/Hz)	% w.r.t Reference
1	3	0.988	1.782	+ 80%

Additional benefits from MIMO operation is for further study.

8.1.3 Evaluation of OFDM based Multicast for evolved UTRA

The initial evaluation presented in Table 8.1.2-1 is based on cases defined in Table A.2.1.1-1 except for the bandwidth which has been set to 5 MHz. The results assume single frequency network operation (SFN), that is all cells in the system transmit the same data at the same time.

Table 8.1.3-1. Spectral Efficiency of OFDM based Multicast for E-UTRA

Case	Band (MHz)	Site to site distance (m)	Speed (kph)	OFDM SFN Multicast 1% BLER 95% coverage (Mbps)
1	2000	500	3	> 5.5 (1.1 b/s/Hz)
2	2000	500	30	> 5.5 (1.1 b/s/Hz)
3	2000	1732	3	< 2.5 (0.5 b/s/Hz)
4	900	1000	3	> 5.5 (1.1 b/s/Hz)

OFDMA based multicast offers potential for significant gains over Rel-6 MBMS. However, these performance gains rely on tightly time synchronized transmission from all cells and are highly sensitive to the combination of band of operation and the site to site distance as illustrated by the performance for case 3 as compared to other cases.

8.2 Analysis of UE complexity

8.2.1 WCDMA based evolved UTRA downlink

8.2.1.1 Baseband

The baseband complexity can be divided in terms of memory and processing. The processing is dominated by the decoder and the receiver front end (user separation, demodulation and channel equalization). The complexity of the decoder is related to the peak data rate. For CDMA based signal the complexity of the receiver front end is essentially linked to the channel equalization.

Receiver front end complexity evaluation for receiver based on frequency domain equalizer shows that the UE has to perform two FFT operations; furthermore a decision feedback can be added to further enhance the equalization performance; a first order measure of the decision feedback block complexity indicates that the complexity is about the same as the complexity of an FFT operation.

One should note that the performance enhancements associated with advance equalizer receivers will also benefit systems which operate Release 5 UTRA-FDD (HS-PDSCH).

8.3 Analysis of Node B impacts

8.3.1 WCDMA based evolved UTRA downlink

8.3.1.1 Baseband

The WCDMA based E-UTRA downlink relies on the existing WCDMA channel structure and procedures and therefore Release 6 Node B should be compatible with the E-UTRA channels structure. The multi-carrier component affects mostly the scheduler and interfaces between the channel elements and the scheduler. The scheduler has to simultaneously control resource allocation across multiple carriers for a UE instead of one per UE in Release 6. The interface from and to each channel element with the scheduler may or may not have to be modified depending on the existing implementation and whether joint scheduling across carriers is supported. No fundamental Node-B complexity issue has been identified for the WCDMA based E-UTRA downlink.

9 UL Concepts

Four basic concepts are proposed in uplink:

- 1 SC-FDMA (FDD / [TDD])
- 2 OFDMA (FDD / [TDD])
- 3 MC-WCDMA(FDD)
- 4 MC-TD-SCDMA (TDD)

9.1 SC-FDMA (FDD / [TDD])

9.1.1 Basic transmission scheme

The basic uplink transmission scheme is single-carrier transmission (SC-FDMA) with cyclic prefix to achieve uplink inter-user orthogonality and to enable efficient frequency-domain equalization at the receiver side. Frequency-domain generation of the signal, sometimes known as DFT-spread OFDM, is assumed and illustrated in Figure 9.1.1-1. This allows for a relatively high degree of commonality with the downlink OFDM scheme and the same parameters, e.g., clock frequency, can be reused,

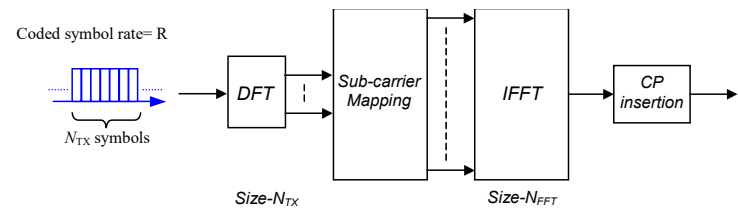


Figure 9.1.1-1 Transmitter structure for SC-FDMA.

The sub-carrier mapping determines which part of the spectrum that is used for transmission by inserting a suitable number of zeros at the upper and/or lower end in Figure 9.1.1-2. Between each DFT output sample $L-1$ zeros are inserted. A mapping with $L=1$ corresponds to localized transmissions, i.e., transmissions where the DFT outputs are mapped to consecutive sub-carriers. With $L>1$, distributed transmissions result, which are considered as a complement to localized transmissions for additional frequency diversity.

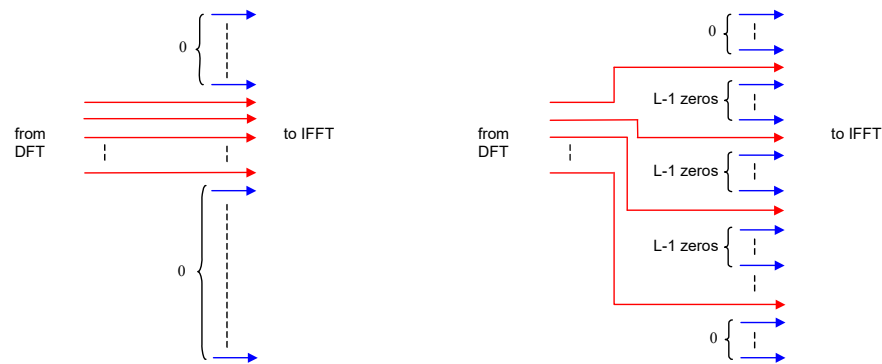
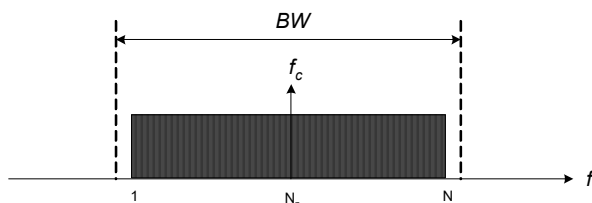


Figure 9.1.1-2 Localized mapping (left) and distributed mapping (right).

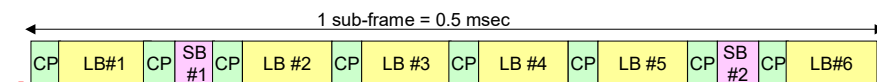
The physical mapping to the N available sub-carriers per one DFT-SOFDM symbol in the RF spectrum shall be performed as illustrated in the figure below, where f_c is carrier frequency.

**Figure 9.1.1-3. Physical Mapping of one DFT-SOFDM symbol in RF frequency domain**

Based on Table 9.1.1-1, when the transmission BW is 1.25/2.5/5/10/15/20 MHz, N is 75/150/300/600/900/1200, and N_n is 38/75/150/300/450/600, respectively.

The basic sub-frame structure for the uplink transmission is given in Figure 9.1.1-4 using two short blocks (SB) and six long blocks (LB) per sub-frame. Short blocks are used for reference signals for coherent demodulation and/or control/data transmission. Long blocks are used for control and/or data transmission. Note that the data could include either or both of scheduled data transmission and contention based data transmission. Furthermore, the same sub-frame structure is used for both localized and distributed transmission.

The numerology for the different spectrum allocations is shown in Table 9.1.1-1. The minimum TTI for uplink transmission is equal to the uplink sub-frame duration. Similar to the downlink, the possibility to concatenate multiple sub-frames into longer uplink TTIs should be considered. In this case, the TTI can either be a semi-static or dynamic transport channel attribute. In case of a semi-static TTI, the TTI is set through higher layer signalling. In case of a dynamic TTI, the number of sub-frames concatenated can be dynamically varied for at least the initial transmission and possibly for retransmissions. It is to be determined to what extent a dynamic TTI can reduce higher layer protocol overhead (e.g. MAC, RLC), L1 overhead (e.g. CRC), and ACK/NACK feedback, as well as reducing latency by reducing segmentation of IP packets. It is initially assumed that the Network (e.g. Node-B) would control the TTI. The interaction between dynamic TTI, signaling errors, HARQ procedure (time synchronous vs. asynchronous including adaptive or non-adaptive characteristics) and UE complexity needs to be investigated.

**Figure 9.1.1-4. Sub-frame format with two short blocks/sub-frame****Table 9.1.1-1. Parameters for Uplink Transmission Scheme using BW efficiency of ~90%**

Spectrum Allocation (MHz)	Sub-frame duration (ms)	Long block size ($\mu\text{s}/\#$ of occupied subcarriers / samples* ²)	Short block size ($\mu\text{s}/\#$ of occupied subcarriers / samples)	CP duration ($\mu\text{s}/\text{samples}$ * ¹)
20	0.5	66.67/1200/2048	33.33/600/1024	$(4.13/127) \times 7$, $(4.39/135) \times 1^*$
15	0.5	66.67/900/1536	33.33/450/768	$(4.12/95) \times 7$, $(4.47/103) \times 1^*$
10	0.5	66.67/600/1024	33.33/300/512	$(4.1/63) \times 7$,

				$(4.62/71) \times 1^*$
5	0.5	66.67/300/512	33.33/150/256	$(4.04/31) \times 7,$ $(5.08/39) \times 1^*$
2.5	0.5	66.67/150/256	33.33/75/128	$(3.91/15) \times 7,$ $(5.99/23) \times 1^*$
1.25	0.5	66.67/75/128	33.33/38/64	$(3.65/7) \times 7,$ $(7.81/15) \times 1^{*1}$

*1: $\{(x1/y1) \times n1, (x2/y2) \times n2\}$ means $(x1/y1)$ for $n1$ reference signal or data blocks and $(x2/y2)$ for $n2$ reference signal or data blocks

*2: FFT size = samples

Note that the largest CP duration includes guard time for ramp up + ramp down time

For E-UTRA TDD, the frame structure corresponding to Table 9.1.1-1 is supported. In addition, a second frame structure is also supported with the intention of providing co-existence with LCR UTRA TDD. The sampling frequency, FFT size, sub-carrier spacing, and number of occupied sub-carriers is the same as for Table 9.1.1-1. However, with this alternative frame structure described in section 6.2.1.1, the basic timeslot structure for the uplink transmission is given in Figure 9.1.1-5 using two short blocks (SB) and eight long blocks (LB) per timeslot. The uplink numerology for the different spectrum allocations are listed in Table 9.1.1-2.

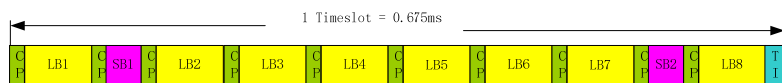


Figure 9.1.1-5 Timeslot format with two short blocks/timeslot

Table 9.1.1-2 Parameters for Uplink Transmission Scheme using BW efficiency of ~90%

Spectrum Allocation (MHz)	Timeslot duration (ms)	Long block size ($\mu\text{s}/\#$ of occupied subcarriers / samples*2)	Short block size ($\mu\text{s}/\#$ of occupied subcarriers / samples)	CP duration ($\mu\text{s}/\text{samples}^*$)	Timeslot Interval (us/samples)
20	0.675	66.67/1200/2048	33.33/600/1024	$(6.71/206) \times 9,$ $(6.97/214) \times 1^*$	7.68/236
15	0.675	66.67/900/1536	33.33/450/768	$(6.77/156) \times 9,$ $(7.11/164) \times 1^*$	6.94/160
10	0.675	66.67/600/1024	33.33/300/512	$(6.71/103) \times 9,$ $(7.22/111) \times 1^*$	7.42/114
5	0.675	66.67/300/512	33.33/150/256	$(6.64/51) \times 9,$ $(7.67/59) \times 1^*$	7.54/58
2.5	0.675	66.67/150/256	33.33/75/128	$(6.51/25) \times 9,$ $(8.58/33) \times 1^*$	7.80/30
1.25	0.675	66.67/75/128	33.33/38/64	$(6.25/12) \times 9,$ $(10.4/20) \times 1^{*1}$	8.32/16

*1: $\{(x1/y1) \times n1, (x2/y2) \times n2\}$ means $(x1/y1)$ for $n1$ reference signal or data blocks and $(x2/y2)$ for $n2$ reference signal or data blocks

*2: FFT size = samples

9.1.1.1 Modulation scheme

The studied uplink data-modulation schemes are $\pi/2$ -shift BPSK, QPSK, 8PSK and 16QAM.

9.1.1.2 Multiplexing including reference signal structure

9.1.1.2.1 Uplink data multiplexing

The channel-coded, interleaved, and data-modulated information [Layer 3 information] is mapped onto SC-FDMA time/frequency symbols. The overall SC-FDMA time/frequency resource symbols can be organized into a number of resource units (RU). Each RU consists of a number (M) of consecutive or non-consecutive sub-carriers during the N long blocks within one sub-frame (See section 9.1.1). To support the localized and distributed transmission (See section 9.1.1), two types of RUs are defined as follows:

- Localized RU (LRU), which consists of M consecutive sub-carriers during N long blocks.
- Distributed RU (DRU), which consists of M equally spaced non-consecutive sub-carriers during N long blocks.

The granularity of the RU should be able to be matched to the expected minimum payload. The size of the baseline LRU and DRU is same and is denoted as S_{RU} , which is equal to $M \times N$, where $M=25$ and N is equal to the number of long blocks in a sub-frame. This results in the number of RUs depending on system bandwidth shown in Table 9.1.1.2.1-1 ~~xxx~~.

Table 9.1.1.2.1-1 Bandwidth occupied by a resource unit and number of resource units dependent on bandwidth.

Bandwidth (MHz)	1.25	2.5	5.0	10.0	15.0	20.0
Bandwidth (kHz) occupied by a resource unit	375	375	375	375	375	375
Number of available resource units	3	6	12	24	36	48

Using other values such as, e.g. $M=15$ or $M=12$ or $M=10$ or M equal to other values can be considered based on the outcome of the interference coordination study.

One or more RUs can be assigned to a UE by the Node B. When more than one LRUs are assigned to a UE, they should be contiguous in frequency domain. When more than one DRUs are assigned to a UE, the sub-carriers assigned should be equally spaced. The multiplexing of localized and distributed transmission is FFS.

The information required by the UE to correctly identify its resources assigned must be made available to the UE by the scheduler. The detailed signalling support is FFS.

9.1.1.2.2 Uplink reference-signal structure

As indicated in Section 9.1.1, uplink reference signals are transmitted within the two short blocks, which are time-multiplexed with long blocks. Uplink reference signals are received and used at the Node B for the following two purposes:

- Uplink channel estimation for uplink coherent demodulation/detection
- Possible uplink channel-quality estimation for uplink frequency- and/or time-domain channel-dependent scheduling

Provided that uplink transmissions are received in a time-aligned fashion (within the cyclic-prefix tolerance), multiple mutually orthogonal reference signals can be created. Multiple such mutually orthogonal uplink reference signals can be allocated to

- A single multi-transmit-antenna UE to support e.g. uplink multi-layer transmission (MIMO)

- Different UEs within the same Node B

As shown in Figure 9.1.1.2.2-1, the uplink reference-signal structure should allow for:

- Localized reference signals occupying a continuous spectrum.
- Distributed reference signals occupying a comb-shaped spectrum.

Note that, due to the use of the short block for the transmission of reference-signals, the “sub-carrier bandwidth”, is twice the “sub-carrier bandwidth” for data transmission in long blocks.

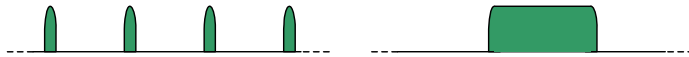


Figure 9.1.1.2.2-1 Distributed (left) and localized (right) reference-signal structure

Orthogonality between uplink reference signals can be achieved using the following methods:

- By transmitting each uplink reference signal across a distinct set of sub-carriers, as in “Figure 9.1.1.2.2-2 left.” This solution achieves “signal orthogonality in the frequency domain” and applies to both localized and distributed reference-signal structures. This approach is referred to as FDM below.
- By constructing reference signals that are orthogonal in the “code domain”, with the signals transmitted across a common set of sub-carriers (example with contiguous sub carriers in Figure 9.1.1.2.2-2 right). As an example, individual reference signals may be distinguished by a specific cyclic shift of a single CAZAC sequence. This approach is referred to as CDM below.
- Orthogonality in the time domain
- A combination of the methods above

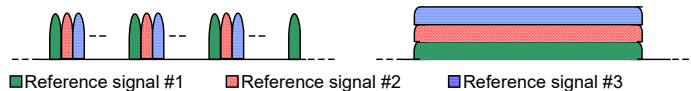


Figure 9.1.1.2.2-2 Reference-signal orthogonality in frequency domain (left) and “code” domain (right) respectively.

Note that orthogonality in the frequency domain is also possible for a localized reference-signal structure.

The applicability of different reference-signal structures to different transmission structures is as follows.

Reference-signal for demodulation/detection in case of localized data transmission:

- To multiplex reference-signals from different UEs occupying different data spectrum, FDM is used.
- Localized reference signal occupying the same spectrum as data transmission in both short blocks or
- Distributed reference signal confined within the same bandwidth as the data transmission but occupying a fraction of the data spectrum can be used in both short blocks. This configuration can be used, for example, to support multiple antenna transmission from a UE, where different antennas could occupy different sets of “comb fingers”.
- Multiplexing of reference signals for the case of a UE with multiple antennas or multiple UEs in MU-MIMO is to be studied further.
- Reference signal occupying at least partly different spectrum than data in at least one short block. This allows for channel-quality estimation also for other frequencies than that used for data transmission and, as a consequence, allows for uplink channel-dependent scheduling

Reference-signal for demodulation/detection in case of distributed data transmission:

- Reference signal distributed on both short blocks to allow for channel estimation of the distributed data. As mentioned, for FDM, due to the use of short blocks (SB) for reference-signal transmission, each reference-signal “comb finger” is twice as large as the corresponding “comb-finger” for the distributed data transmissions in the long blocks (LB). Thus to provide better frequency sampling of the channel for the channel estimation, frequency-domain staggering of the reference signals of SB2, relative to SB1 may be applied when both the SB1 and SB2 are used for reference-signal for demodulation/detection of distributed data transmission as shown in Figure 9.1.1.2.2-3. Note that the staggering of distributed reference signals in SB1 and SB2 could also be used in case of localized data transmission.

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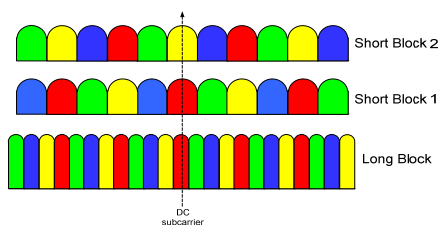


Figure 9.1.1.2.2-3 An example of Frequency-domain staggering of the reference signals of SB2, relative to SB1

- Reference signal that occupies a set of sub-carriers, which may overlap the sub-carriers which are used by the long block (data). An example is portrayed in Figure 9.1.1.2.2-4.

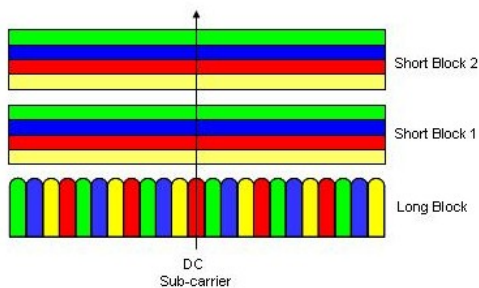


Figure 9.1.1.2.2-4 An example of overlap the sub-carriers which are used by the long block (data).

- For multiplexing reference-signals from different UEs within the same Node B, distributed FDM and/or CDM is used.

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Reference-signal for uplink channel-quality estimation (channel sounding):

- Reference signal may occupy at least partly different spectrum than data transmission. This allows for channel-quality estimation also for other frequencies than that used for data transmission and, as a consequence, allows for uplink channel-dependent scheduling.
- For multiplexing reference-signals from different UEs within the same Node B, distributed FDM and/or CDM is used.
- Multiplexing of reference signals for the case of a UE with multiple antennas or multiple UEs in MU-MIMO is to be studied further.
- When reference-signal for uplink channel-quality estimation is transmitted with data symbols within the same sub-frame, a part of this reference-signal can also be used for channel estimation for demodulation/detection of the data symbols.

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The two SBs can be used for transmission of reference-signals for different purposes listed above.

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When the reference signals occupying the different size of the spectrum (FFS) are multiplexed into overlapped frequency band, different sub-carriers should be assigned for the reference signals within the overlapping frequency band in order to achieve orthogonal transmission.

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The uplink reference signals are based on CAZAC sequences. Which exact type of CAZAC sequences is FFS.

9.1.1.2.3 Multiplexing of L1/L2 control signaling

There are two types of L1 and L2 control-signaling information:

- data-associated signaling (e.g., transport format and HARQ information), which is associated with uplink data transmission, and
- data-non-associated signaling (e.g., CQI and/or ACK/NACK due to downlink transmissions, and scheduling requests for uplink transmission).

Furthermore, three multiplexing combinations for the uplink pilot, data, and L1/L2 control signaling within a sub-frame are considered for a single UE:

- Multiplexing of pilot, data, and data-associated L1/L2 control signaling
- Multiplexing of pilot, data, and data-associated and data-non-associated L1/L2 control signaling
- Multiplexing of pilot and data-non-associated L1/L2 control signaling

In single-carrier FDMA radio access, time-domain multiplexing is used for the above-mentioned three multiplexing combinations as shown in Figure. 9.1.1.2.3-1, in order to retain the advantageous single-carrier feature with a low PAPR.

Figure. 9.1.1.2.3-2 shows a multiplexing scheme for L1/L2 control signaling, data, and pilot. In Figure 9.1.1.2.3-2(a), both data-associated and data-non-associated control signaling are time-multiplexed with data and pilot within the sub-frame. Furthermore, the data-associated and data-non-associated control ~~signalings~~signalling from multiple UEs are multiplexed in the frequency or/code domains associated with multiple pilot channels. In Figure 9.1.1.2.3-2(b), the data-associated control signaling is time-multiplexed with data similar to the case in Figure 9.1.1.2.3-2(a). The data-non-associated control signaling can also be time-multiplexed with data if UE has UL data transmission. Meanwhile, the data-non-associated control signaling for UEs that transmits only the L1/L2 control, is multiplexed exclusively in a semi-statically assigned time-frequency region. The data-non-associated control signaling of different UEs is multiplexed using the frequency/time/code domain or a hybrid of them within the assigned time-frequency region. The exclusive time-frequency region can be separated into two frequency-time resources. First part can contain data-non-associated control signaling without user identification, e.g. ACK/NACK, and the second part can contain the one with user identification. The possibility for multiplexing of data-non-associated control signaling with data channel by exclusive frequency resource, i.e., frequency-multiplexing, is FFS.

The amount of overhead due to the L1 and L2 signaling and the exact mapping to the time-frequency resources needs further investigation.

Note that Figure 9.1.1.2.3-2 (a) - (b) show localized allocation only but the multiplexing options described above are also applicable to distributed allocation.

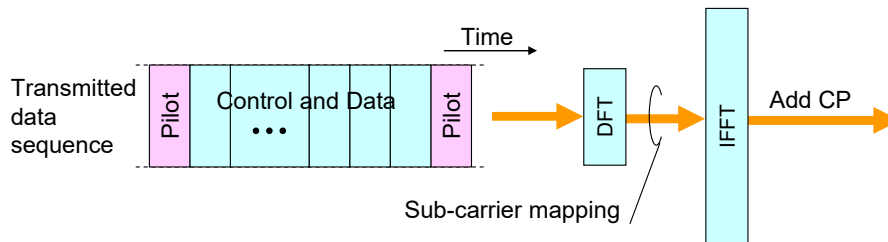
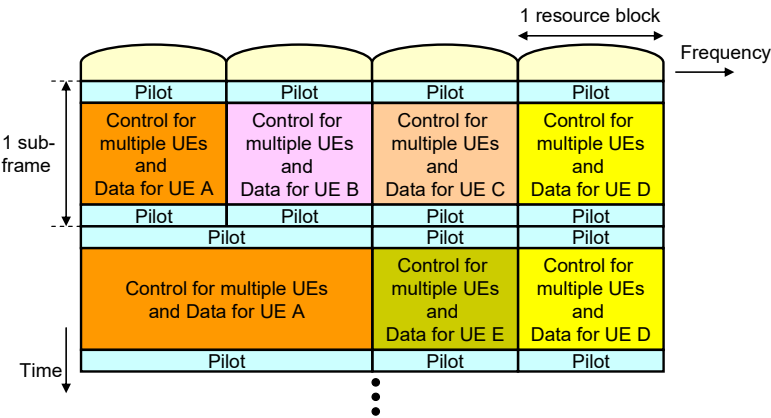


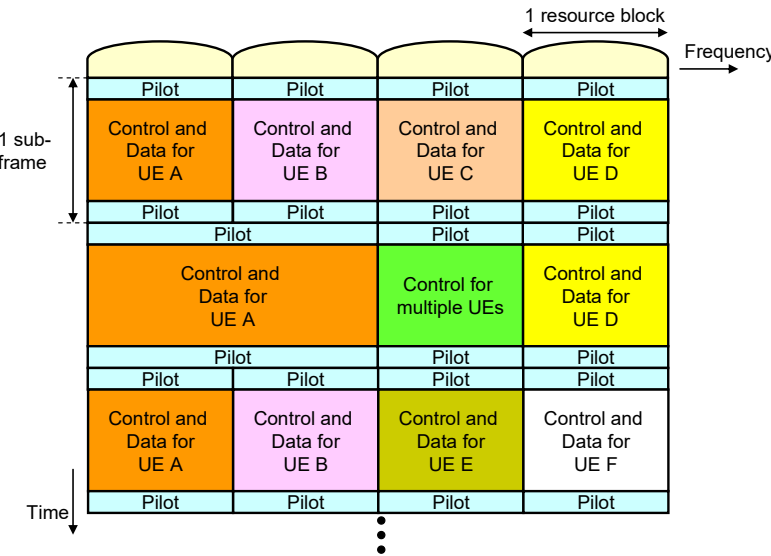
Figure 9.1.1.2.3-1 – Transmission principle of TDM-based multiplexing

(Note: This figure is used for illustration purposes only, and the positions of pilot, control, and data within the sub-frame do not specify the actual configuration.)

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(a) Multiplexing scheme (a)



(b) Multiplexing scheme (b)

Figure 9.1.1.2.3-2 – Multiplexing scheme for L1/L2 control signaling, data, and pilot

(Note: These figures are used for illustration purposes only, and the positions of pilot, control, and data within the sub-frame do not specify the actual configuration.)

9.1.1.2.4 Uplink L1/L2 Control Signaling

Depending on presence or absence of uplink timing synchronization, the uplink L1/L2 control signaling can differ.

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In the case of time synchronization being present, the outband control signaling consists of

- Data-associated control signaling
- CQI
- ACK/NAK
- Synchronous random access (scheduling request, resource request)

Transmission of CQI and ACK/NAK may occur in parallel to data-associated control signaling or synchronized random access. Synchronized random access may not be transmitted simultaneously with data-associated control signaling.

In the case of time synchronization not being present, the outband control signaling consists of

- Non-synchronized random access

9.1.2.4.1.1 Data-associated control signaling

Data-associated control signaling can only be transmitted together with user data. The content is summarized in Table 9.1.2.4.1.1-1.

Table 9.1.2.4.1.1-1 Data-associated control signaling

Field			Size	Comment
HARQ related information	If asynchronous hybrid ARQ is adopted	Hybrid ARQ process number	3	Indicates the hybrid ARQ process the current transmission is addressing.
		Redundancy version	2	To support incremental redundancy.
		New data indicator	1	To handle soft buffer clearing.
	If synchronous hybrid ARQ is adopted	Retransmission sequence number	2	Used to derive redundancy version (to support incremental redundancy) and ‘new data indicator’ (to handle soft buffer clearing).
TF	Transport format		FFS	The uplink transport format (modulation format, transport block size, etc). Only required if UE-based TFC selection is supported.

Note: It is FFS whether asynchronous or synchronous hybrid ARQ operation will be adopted.

Note: It is FFS whether the transport format the UE uses is mandated by the Node B or controlled by the UE.

Note: In case of multi-layer transmission, multiple instances of (parts of) the data-associated control signaling may be required.

9.1.2.4.1.2 CQI

The CQI informs the scheduler about the current channel conditions as seen by the UE. If MIMO transmission is used, the CQI includes necessary MIMO-related feedback.

Table 9.1.2.4.1.2-1 Channel Quality Indicator

Field	Size	Comment
CQI	FFS	

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9.1.2.4.1.3 ACK/NAK

The hybrid ARQ feedback in response to downlink data transmission consists of a single ACK/NAK bit.

Table 9.1.2.4.1.3-1 ACK/NAK

Field	Size	Comment
ACK/NAK	FFS	Up to one bit per downlink transport block. Multiple bits may be required to support downlink multi-layer transmission (if hybrid ARQ operates per layer) and in case of TDD.

9.1.2.4.1.4 Synchronized random access (resource request)

The synchronized random access is used by the UE to request resources for uplink data transmission. It is further described in Section 9.1.2.1.

9.1.2.4.1.5 Non-synchronized random access

The non-synchronized random access is described in Section 9.1.2.1.

9.1.1.3 Channel coding and physical channel mapping

Similar to the downlink, the current assumption is that uplink channel coding for Layer 3 information is based on current UTRA release 6 Turbo coding, possibly extended to lower rates by the extension of additional code polynomials, extended to longer code blocks, and modified by the removal of the tail. However, also similar to the downlink, the use of alternative FEC encoding schemes could be considered if significant benefits in terms of complexity and performance could be shown.

To achieve high processing gain, repetition coding can be used as a complement to FEC.

Uplink channel coding for lower-layer control signaling is TBD.

The control channel is multiplexed in time domain and may preferably be mapped on the symbols from which the CP is constructed. The control channel may be transmitted in one or more data block (number and position are FFS)

9.1.1.4 MIMO and Transmit Diversity

The baseline antenna configuration for uplink single-user MIMO is two transmit antennas at the UE and two receive antennas at the Cell site.

The use of both open loop transmit diversity techniques based on block codes as well as cyclic shift diversity, open-loop and closed-loop MIMO techniques, e.g. spatial division multiplexing (SDM) and precoding, should be considered. For the closed-loop mode, techniques for reducing signaling overhead should be evaluated. The possibility for single user higher-order uplink MIMO (more than two TX/RX antennas) should be considered.

Transmit antenna selection at the UE, which assumes fewer RF chains than the number of transmit antennas (e.g. 1 RF chain and 2 transmit antennas), should be considered to potentially lower the UE complexity.

The possibility for SDMA should also be considered. A specific example of SDMA corresponds to a (2x2) virtual MIMO, where two UEs, each of which transmitting on a single antenna, share the same time and frequency resource allocation. These UEs apply mutually orthogonal reference signal patterns in order to simplify Cell site processing (cancellation). Note that from the UE perspective difference between (2x2) virtual MIMO and single antenna transmission is only the use of a reference signal pattern allowing for "pairing" with another UE.

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Figure 9.1.2.1.1.1-1 TDM/FDM option example using 1 sub-frame and preamble-only transmission in the random access burst

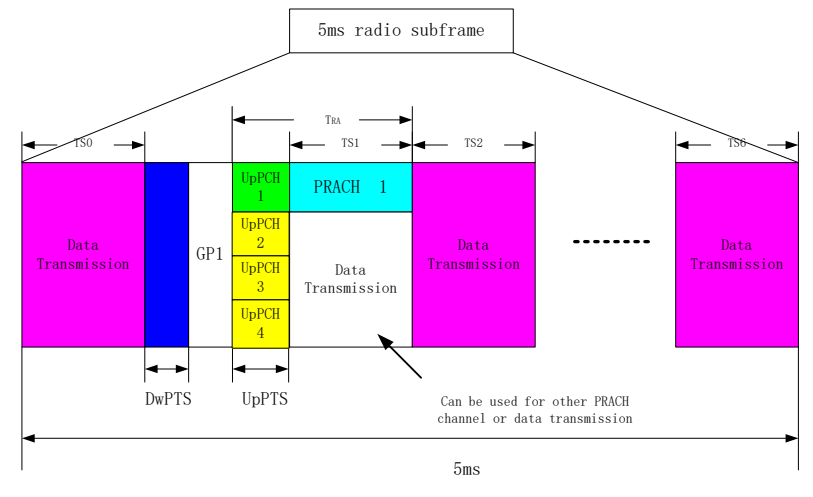


Figure 9.1.2.1.1-2 TDM/FDM option example for coexisting LCR-based frame structure (TDD mode) for optimum coverage scenario and preamble-only transmission in the UpPCH channel

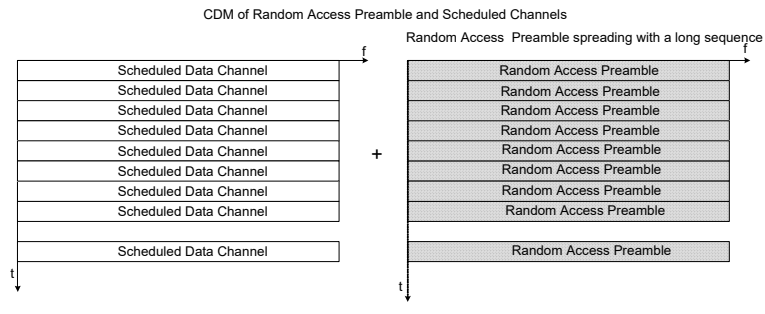


Figure 9.1.2.1.1-3 Example of CDM of Scheduled Channels and random access preamble

9.1.2.1.1.2 Preamble and message payload

The non-synchronized random access preamble is used for time alignment, signature detection etc. The message payload comprises any additional associated signaling information. It is FFS whether the message payload can be transmitted in the random access burst along with the preamble as shown in Figure 9.1.2.1.2-1, or on the shared data channel upon preamble detection and UL resource allocation by the Node B.

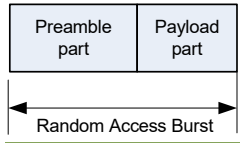


Figure 9.1.2.1.2-1 Example of random access burst

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9.1.2.1.1.3 Non-synchronized random access procedure

Prior to attempting a non-synchronized random access, the UE shall synchronize to the downlink transmission.

Two possibilities for the random access procedure are considered:

- Approach#1: Figure 9.1.2.1.1.3-1 outlines this approach, where the Node B responds to the non-synchronized random access attempt with timing information to adjust the uplink transmission timing and an assignment of uplink resources to be used for transmission of data or control signalling (possibly including any message payload (e.g. UE ID) not included in the preamble) using the shared data channel. It may be noted that the timing information can also be combined with the uplink data resource allocation. Furthermore, the uplink data resource allocation may be implicitly indicated by associating a reserved time frequency region with a preamble sequence.
- Approach#2: Figure 9.1.2.1.1.3-2 outlines this approach, where the Node B responds to the non-synchronized random access attempt preamble with timing information and resource allocation for transmission of scheduling request (and possibly any additional control signalling or data). UE then sends the scheduling request at the assigned time-frequency resource using the shared data channel or physical random access channel (for co-existing LCR-TDD based frame structure). The Node B adjusts the resource allocation according to the scheduling request from the UE.

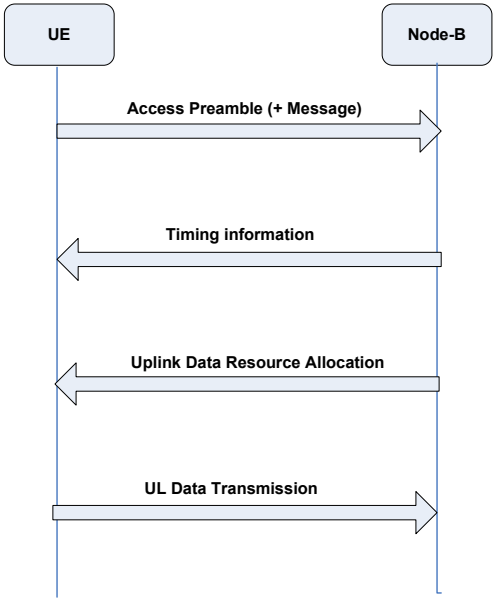


Figure 9.1.2.1.1.3-1. Approach#1, Non-Synchronized Access

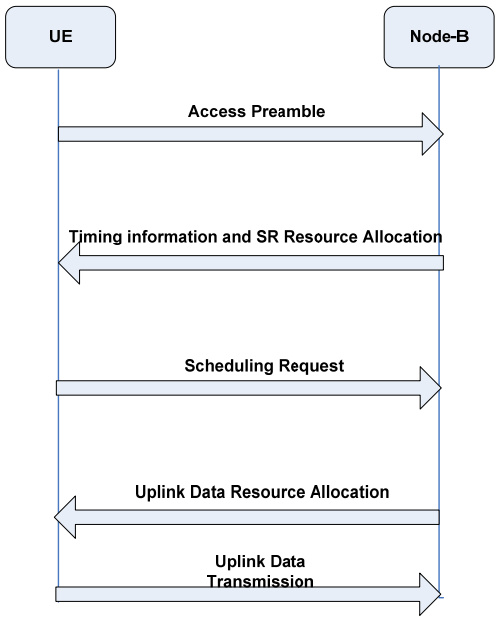


Figure 9.1.2.1.1.3-2 Approach#2, Non-Synchronized Access

9.1.2.1.1.4 Power control for non-synchronized random access

The power control scheme shall be designed assuming no intra-cell interference from data transmissions (i.e., TDM/FDM operation).

Open loop power control is used to determine the initial transmit power level. It is possible to vary the random access burst transmit power between successive bursts using:

- a) Power ramping with configurable step size including zero step size for both FDD and TDD case
- b) Per-burst open loop power determination for TDD case only

9.1.2.1.2 Synchronized random access:

The synchronized random access procedure may be used when the UE uplink is time synchronized by the Node B. The purpose is for the UE to request resources for uplink data transmission. One of the objectives of the synchronized random access procedure is to reduce the overall latency.

9.1.2.1.2.1 Time Frequency Structure

Synchronized random access and data transmission are also time and/or frequency multiplexed. An example of synchronized random access (applicable for FDD, TDD and co-existing LCR TDD) is shown in Figure 9.1.2.1.2.1-1. It may be noted that the number of long blocks (LB) shown in the figure is for illustration only. The minimum bandwidth, BW_{RA}, allocated for synchronized random access transmission is equal to the bandwidth of the uplink resource allocation unit (e.g. 375 KHz). Also, the random access transmission can use a larger bandwidth, or multiple random access channels using the minimum bandwidth can be defined. Multiple random access channels might be

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useful for selecting a best block using frequency selective channel characteristics (TDD mode). The length of the synchronized random access burst can be adjusted (e.g. on a cell basis depending on the cell size) to optimize the overhead/latency versus coverage trade-off. It is FFS on how this adjustment is made (e.g. static, semi-static, dynamic). Synchronized random access can be done every x sub-frames (e.g. $x=2$).

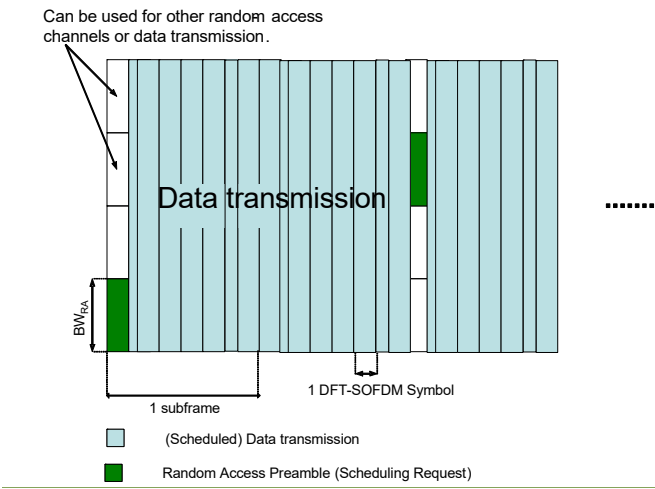


Figure 9.1.2.1.2.1-1 Example of Synchronized Random Access

9.1.2.1.2.2 Synchronized Random Access Procedure

For synchronized random access, Figure 9.1.2.1.1.3-1 and 9.1.2.1.1.3-2 also apply, except the timing information may not be transmitted.

9.1.2.1.2.3 Preamble Design Principle

The preamble sequences shall be designed assuming no intra-cell interference from data transmissions (i.e., TDM/FDM operation).

The random access channel sequence(s) (e.g. based on CAZAC/GCL) used to generate the transmitted random access preamble waveforms should have the following properties:

- 1. Good detection probability while maintaining low false alarm rate e.g. by maximizing post-decoder $E_s/(N_t+N_e)$ for a occupied random access channel preamble where N_e is the residual interference due to other random access channel transmissions in a given random access channel and N_t is thermal noise.
- 2. Number of random access channel preamble waveforms should be defined to handle the maximum expected multiple access scenarios (traffic load) while guaranteeing low collision probability.
- 3. Enable accurate timing estimation (e.g. good autocorrelation properties and sufficient occupied BW).
- 4. Low power de-rating (low CM/PAPR).

9.1.2.2 Scheduling

The uplink should allow for both scheduled (Node B controlled) access and contention-based access.

In case of scheduled access the UE is dynamically allocated a certain frequency resource for a certain time (i.e. a time/frequency resource) for uplink data transmission. Downlink control signaling informs UE(s) what resources and respective transmission formats have been allocated. The decision of which user transmissions to multiplex within a given sub-frame may for example be based on

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- QoS parameters and measurements,
- payloads buffered in the UE ready for transmission,
- pending retransmissions,
- uplink channel quality measurements
- UE capabilities,
- UE sleep cycles and measurement gaps/periods,
- system parameters such as bandwidth and interference level/patterns,
- etc.

Methods to reduce the control signaling overhead, e.g., pre-configuring the scheduling instants (persistent scheduling) and grouping for conversational services, should be considered. Transmission of the reference signals to facilitate the uplink channel quality measurements should be investigated. In addition it should be determined if grouping can more efficiently use time frequency resources resulting in higher capacity.

However, some time/frequency resources can be allocated for contention-based access. Within these time/frequency resources, UEs can transmit without first being scheduled. As a minimum, contention-based access should be used for random-access and for request-to-be-scheduled signaling

In unpaired spectrum, system capacity may be improved through the use of localised FDMA contention-based access channels. The UE may select the access channel based upon knowledge of the channel state information measured on a recent downlink sub-frame

9.1.2.3 Link adaptation

Uplink link adaptation is used in order to guarantee the required minimum transmission performance of each UE such as the user data rate, packet error rate, and latency, while maximizing the system throughput.

For this purpose, uplink link adaptation should effectively utilize a combination of the adaptive transmission bandwidth accompanied with channel-dependent scheduling, transmission power control, and the adaptive modulation and channel coding rate.

Three types of link adaptation are performed according to the channel conditions, the UE capability such as the maximum transmission power and maximum transmission bandwidth etc., and the required QoS such as the data rate, latency, and packet error rate etc. In particular, the three schemes are controlled by channel variation as link adaptation. The basic features of the three link adaptation methods are as follows.

- Adaptive transmission bandwidth
 - The transmission bandwidth of each UE is determined at least based on the averaged channel conditions, i.e., path loss and shadowing variation, in addition to the UE capability and required data rate. Furthermore, the adaptive transmission bandwidth based on fast frequency selective fading accompanied with frequency-domain channel-dependent scheduling should be investigated during the Study Item phase.
- Transmission power control
 - Transmission power control guarantees the required packet error rate and bit error rate regardless of the channel conditions.
 - The target of the received SINR can be different for different UEs in order to increase the system throughput by reducing the inter-cell interference. Thus, the target of the received SINR for the UE at the cell boundary can be smaller than that for the UE in the cell vicinity. The target for the received SINR should also be controlled considering fairness among UEs.
- Adaptive modulation and channel coding rate
 - The adaptive modulation and channel coding rate increases the achievable data rate (frequency efficiency) according to the channel conditions.
 - After the transmission bandwidth and transmission power are determined, the adaptive modulation and channel coding rate control selects the appropriate modulation and channel coding rate that maximizes the frequency efficiency while satisfying the required QoS such as the packet error rate and latency.
 - The same coding and modulation is applied to all resource units assigned to which the same L2 PDU is mapped on the shared data channel scheduled for a user within a TTI. This applies to both localized and distributed transmission. The overall coding and modulation is illustrated in Figure 9.1.2.3-1.

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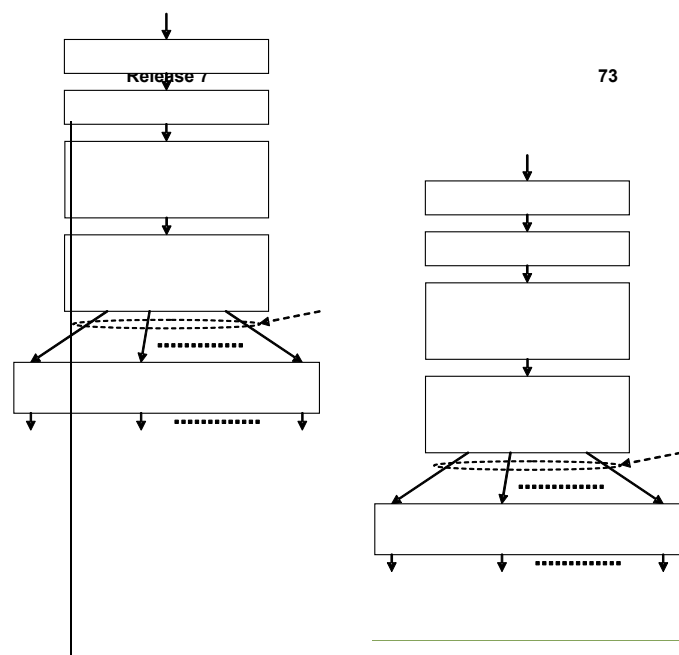


Figure 9.1.2.3-1 – Resource unit~~block~~-common adaptive modulation and resource ~~block~~unit-common channel coding rate (for both localized and distributed transmission).

The control update interval for each of the three link adaptation methods should be jointly investigated from the viewpoint of the achievable performance such as the throughput, packet error rate, and latency as well as the required signaling overhead.

If the uplink HARQ operation is synchronous in time, two different kinds of link adaptation techniques may be considered:

- The associated UL assignment is sent by the Node-B for the first transmission and all subsequent retransmissions
 - The Node-B has the flexibility to change the modulation order, the set of coded rate-matched bits and resource ~~block~~-unit allocation in an adaptive manner
 - For the retransmissions, the Node-B only needs to signal the transmission attributes which are adapted on a non-predetermined basis
- The associated UL assignment is sent by the Node-B only for the first transmission
 - The number of allocated resource ~~blocks~~-units is fixed.
 - The sequence of resource ~~block~~-unit mapping, modulation order and set of coded rate-matched bits for each retransmission is pre-determined and known to the Node-B and UE.

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The impact of such schemes on link and system performance needs to be evaluated further.

9.1.2.4 Power control

For the uplink, transmission power control, being able to compensate for at least path loss and shadowing should be supported. The benefits and possible means for compensating also for fast (multi-path) fading should be investigated during the Study Item phase.

9.1.2.4.1 Slow Power Control

By performing the slow power control scheme on each UE uplink transmission power, the average inter-cell interference level received at the Node-B is effectively reduced.

The slow power control may be implemented in each Node-B by sending slow updating power control signaling. Alternatively, each UE can derive its own transmission power according to the path loss measurement from downlink pilot. ~~No coordination is needed between the Node-Bs.~~

To achieve good trade-off of the cell-edge performance and the overall spectral efficiency, slow power control scheme that compensates a fraction of the path loss and shadowing should be considered.

9.1.2.4.2 Power Control based upon neighbour cell load

Power control of uplink transmissions may be used to control the degree of inter-cell interference generated by a UE into its neighbouring cells. It should be considered whether these mechanisms require the UE to receive and decode information from neighbour cells (e.g. load indication) and the impacts of this should be investigated.

9.1.2.5 HARQ

Uplink HARQ should be based on Incremental Redundancy. Note that Chase Combining is a special case of Incremental Redundancy and is thus implicitly supported as well.

The N-channel Stop-and-Wait protocol is used for uplink HARQ.

HARQ can be classified as being synchronous or asynchronous:

- Synchronous HARQ implies that (re)transmissions for a certain HARQ process are restricted to occur at known time instants. No explicit signaling of the HARQ process number is required as the process number can be derived from, e.g., the subframe number.
- Asynchronous HARQ implies that (re)transmission for a certain HARQ process may occur at any time. Explicit signaling of the HARQ process number is therefore required.

In principle, synchronous operation with an arbitrary number of simultaneous active processes at a time instant could be envisioned. In this case, additional signaling may be required. Asynchronous operation already supports an arbitrary number of simultaneous active processes at a time instant. Furthermore, note that, in a synchronous scheme, the transmitter may choose not to utilize all possible retransmission instants, e.g., to support pre-emption. This may require additional signaling.

The various forms of HARQ schemes are further classified as adaptive or non-adaptive in terms of transmission attributes, e.g., the Resource ~~Block-unit~~ (RUB) allocation, Modulation and transport block size, and duration of the retransmission. Control channel requirements are described for each case.

- Adaptive implies the transmitter may change some or all of the transmission attributes used in each retransmission as compared to the initial transmissions (e.g. due to changes in the radio conditions). Hence, the associated control information needs to be transmitted with the retransmission. The changes considered are:
 - Modulation
 - Resource ~~UnitBlock-~~ allocation
 - Duration of transmission
- Non-Adaptive implies that changes, if any, in the transmission attributes for the retransmissions, are known to both the transmitter and receiver at the time of the initial transmission. Hence, the associated control information need not be transmitted ~~forwith~~ the retransmission.

With those definitions, the HS-DSCH in WCDMA uses an adaptive, asynchronous HARQ scheme, while E-DCH in WCDMA uses a synchronous, non-adaptive HARQ scheme.

The capability of adaptively being able to change the packet format (i.e., adaptive IR) and the transmission timing (i.e., asynchronous IR) yields an adaptive, asynchronous IR based HARQ operation. Such a scheme has the potential of optimally allocating the retransmission resources in a time varying channel. For each HARQ retransmission, control information about the packet format needs to be transmitted together with the data sub-packet.

Synchronous HARQ transmission entails operating the system on the basis of a predefined sequence of retransmission packet format and timing.

The benefits of synchronous HARQ operation when compared to asynchronous HARQ operation are:

- Reduction of control signalling overhead. from not signalling HARQ channel process number
- Lower operational complexity if non-adaptive operation is chosen
- Possibility to soft combine control signalling information across retransmissions for enhanced decoding performance if non-adaptive operation is chosen.

Therefore, for the purpose of the feasibility study, synchronous HARQ operation is assumed for the SC-FDMA based E-UTRA uplink. The impact of ACK/NAK signalling errors on synchronous HARQ operation needs further study.

Adaptive asynchronous HARQ is for further study.

Depending on the actual L1/L2 requirements, asynchronous HARQ may best address the issues of:

- Scheduling flexibility if fully adaptive operation is selected and if both localized and distributed allocations are selected.
- Support for multiple simultaneous (in the same (set of) subframe(s)) independent HARQ processes
- Flexibility in scheduling of retransmissions

The desirability of particular L1/L2 features will determine the degree of adaptive operation.

9.1.2.6 Uplink timing control

In order to keep time alignment between uplink ~~transmission~~transmissions from multiple UEs at the receiver side, timing-control commands, commanding UEs to advance or retract the respective transmit timing, can be transmitted on the downlink. Two alternatives for timing control commands can be considered:

- Binary timing-control commands implying forward/backward of the transmit timing a certain step size $x \mu s$ [x TBD] transmitted with a certain period $y \mu s$ [y TBD].
- Multi-step timing-control commands being transmitted on the downlink on a per-need basis.

As long as a UE carries out uplink data transmission, this can be used by the receiving cell site to estimate to uplink receive timing and thus as a source for the timing-control commands. When there is no data available for uplink, the UE may carry out regular uplink transmissions (uplink synchronization signals) with a certain period, to continue to enable uplink receive-timing estimation and thus retain uplink time alignment. In this way, the UE can immediately restart uplink-orthogonal data transmission without the need for a timing re-alignment phase.

If the UE does not have uplink data to transmit for a longer period, no uplink transmission should be carried out. In that case, uplink time alignment may be lost and restart of data transmission must then be preceded by an explicit timing-re-alignment phase to restore the uplink time alignment.

9.1.2.7 Inter-cell interference mitigation

The basic approaches to inter-cell interference mitigation for uplink are as follows.

- Co-ordination/avoidance i.e. by fractional re-use of time/frequency resources
- Inter-cell-interference randomization
- Inter-cell-interference cancellation
- Frequency domain spreading

Regarding the Frequency domain spreading, a spreading gain can be obtained either explicitly by spreading modulation symbols over multiple carriers or implicitly by using repetition code in the channel coding.

The slow power control (9.1.2.4.1) and power control based upon neighbour cell load (9.1.2.4.2) can also be seen as a means for uplink inter-cell-interference mitigation.

In addition, the use of beam-forming antenna solutions at the base station is a general method that can also be seen as a means for uplink inter-cell-interference mitigation.

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It should be noted that the different approaches could, at least to some extent, complement each other i.e. they are not necessarily mutually exclusive.

9.1.2.7.1 Inter-cell-interference co-ordination/avoidance

The common theme of inter-cell-interference co-ordination/avoidance is to apply restrictions or preferences to the uplink scheduling, coordinated between cells. These restrictions can be in the form of restrictions to what time/frequency resources are available to the scheduler or restrictions on the transmit power that can be applied to certain time/frequency resources. Such restrictions for a terminal in a cell will provide the possibility for the improvement in SIR and cell-edge data-rates/coverage, on the corresponding time/frequency resources in a neighbour cell. –Similar to the downlink different assumption can be made regarding UE measurements/reporting needed to support uplink interference co-ordination. In addition to the alternatives valid for the downlink, see Section 7.1.2.6.3, one can also assume that, in support for uplink interference co-ordination, the UE may report its current power level with a reporting rate in the order of once every 50 ms.

Regarding required inter-cell interference co-ordination in support for uplink interference co-ordination, two cases are considered similar to downlink interference co-ordination:

- Static interference co-ordination
Reconfiguration of the restrictions is done on a time scale corresponding to days. The inter-node communication is very limited (set up of restrictions), basically with a rate of in the order of once per day.
- Semi-static interference co-ordination
Reconfiguration of the restrictions is done on a time scale corresponding to seconds or longer. Inter-node communication corresponds to information needed to decide on reconfiguration of the scheduler restrictions (examples of communicated information: traffic-distribution within the different cells, uplink interference contribution from cell A to cell B, etc.) as well as the actual reconfiguration decisions. Signaling rate in to order of tens of seconds to minutes.

9.1.2.7.2 Inter-cell-interference randomization

Similar to downlink, inter-cell-interference randomization in uplink aims at randomizing the interfering signal(s) and thus to allow for interference suppression at the Node B in line with the processing gain.

Methods considered for inter-cell-interference randomization includes:

- *User/Cell-specific scrambling*, applying (pseudo) random scrambling after channel coding/interleaving
- *User/Cell-specific interleaving*, also known as *Interleaved Division Multiple Access (IDMA)* (IDMA requires planning of interleaving sequences)
- *User/Cell-specific frequency hopping*.

A third means for randomization is to apply different kinds of frequency hopping.

With regards to inter-cell-interference randomization, user/cell-specific scrambling and user/cell-specific interleaving (IDMA) basically have the same performance.

A pseudo-random method can be used to generate the user/cell-specific interleaver patterns for IDMA. The number of the available patterns (seeds) is determined by the length of interleaver. A Node B can identify the interleaver pattern of the cell by checking its interleaver pattern ID. The seeds can be reused between “far-spaced” cells in a manner similar to that of frequency reuse in a cellular system.

The benefits from the randomization of the inter-cell interference come without any restriction on the Node B scheduler or receiver type. However, these benefits are achievable only if the transmitted waveform characteristics support the means to randomize the inter-cell interference. Therefore, means to randomize the inter-cell interference experienced in the reception of all the UE signals may be supported by the definition of the UL signal characteristics.

9.1.2.7.3 Inter-cell-interference Cancellation

Fundamentally, inter-cell-interference cancellation aims at interference suppression at the NodeB beyond what can be achieved by just exploiting the processing gain.

Two methods can be considered:

- Spatial suppression by means of multiple antennas at the NodeB.

- Interference cancellation based on detection/subtraction of the inter-cell interference. One example is the application of cell-specific interleaving (IDMA) to enable inter-cell-interference cancellation.

The IDMA based inter-cell-interference cancellation scheme would imply the following requirements on the system:

- Band allocation: The overlapped frequency resource in the “cell edge” area should be reused with the same “band allocation” in the serving and interfering cells respectively. And the “interfering UE” and the “interfered UE” should transmit using the same band.
- Synchronization: Inter-NodeB synchronization is required.
- Intra-cell signalling: When IDMA is used, a NodeB naturally has the knowledge of the interleaver pattern used by the UEs in the cell, hence no extra signalling is needed.
- Inter-cell signalling: Interfering UE configurations (e.g. interleaver pattern ID, modulation scheme, FEC scheme and coding rate) should also be signalled to the interfered NodeB. To cancel the inter-sector interference in uplink, the NodeB naturally has the knowledge of interfering UE, hence no extra signalling or operation is needed. To cancel the inter-NodeB interference, the signalling of interfering UE configurations to the NodeB is realized by detecting the control channel of the interfering UE.

9.1.3 Physical layer measurements

9.1.3.1 Node B measurements

9.2 OFDMA (FDD / [TDD])

9.2.1 Basic transmission scheme

The uplink transmission scheme is based on conventional OFDM using a cyclic prefix as described 7.1.1. The basic transmission parameters such as sub-carrier spacing, sub-frame duration and a cyclic-prefix (CP) duration are defined in Table 7.1.1-1 and are equally applicable to uplink. The need for longer CP durations is FFS.

It may be noted that the specified numerology is for evaluation purpose only.

The minimum TTI for uplink transmission is equal to the uplink sub-frame duration. Similar to the downlink, the possibility to concatenate multiple sub-frames into longer uplink TTIs should be considered.

Note that the sub-carrier spacing is constant regardless of the transmission bandwidth. To allow for operation in differently sized spectrum allocations, the transmission bandwidth is instead varied by varying the number of OFDM sub-carriers.

9.2.1.1 Modulation scheme

9.2.1.2 Multiplexing including pilot structure

Two types of pilot symbols should be considered

- 1.) In band pilots - used for coherent data demodulation, e.g. channel estimation. These pilots are transmitted in the part of the bandwidth used for data transmission.
- 2.) Out of band pilots – used for advanced frequency dependent scheduling and link adaptation. These pilots span a larger bandwidth than the one used for data transmission.

Note that in band pilots may also be used for frequency dependant scheduling and link adaptation.

In-Band-Pilot (IBP) Assignment

Orthogonal in-band pilot symbol patterns are needed in the following cases:

- If a UE transmits on two antennas (Ant A and Ant B) as in the case of MIMO or Tx diversity

- If multiple UEs share the same time and frequency resource, each of the UEs transmitting on a single antenna it is beneficial that UEs use orthogonal pilot patterns (this is described as virtual MIMO, a specific case of SDMA, see section 9.2.1.3).

Orthogonality of in-band pilot symbol patterns can be achieved in the time and/or frequency domain.

Figure 9.2.1.2-1 shows an example of the IBP locations and overheads in the case channel allocation to a UE in the time domain is done in multiple of 7 symbols (a full sub-frame). The exact pilot locations and overhead are FFS.

Figs-9.2.12-2 (a) – (c) show examples of the IBP location and overheads in the case channel allocation in the time domain to a UE is done in multiple of 6 symbols, meaning that the first symbol in a sub-frame may be used for other purposes (e.g. common control signalling). The exact pilot locations and overhead are FFS. Figs-9.2.12-2 (a) – (c) further exemplify different cases of pilot pattern orthogonality:

- Fig 9.2.1.2-2 (a) exemplifies the case of a single UE transmitting on a single antenna for which no orthogonal pilot is used.
- Fig 9.2.1.2-2 (b) exemplifies the case of a UE transmitting on multiple antennas for which orthogonal pilot patterns are transmitted from the multiple antennas
- Fig 9.2.1.2-2 (c) exemplifies the case of multiple UEs, each of which transmitting on a single antenna, sharing the same time and frequency resource. Each UE transmits one orthogonal pilot pattern (virtual MIMO case)

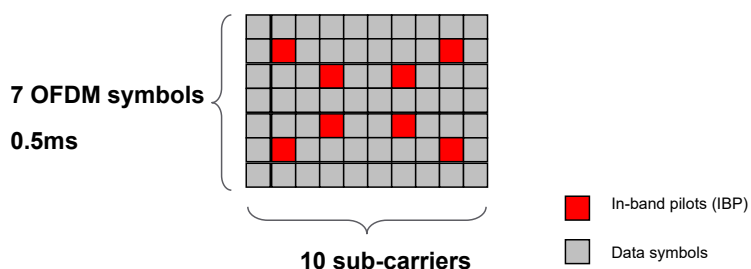


Figure 9.2.1.2-1: Channel allocation in the time domain in multiple of 7 symbols
(Single UE, single antenna transmission case)

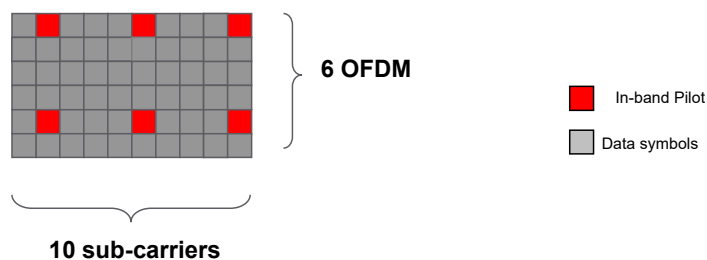


Figure 9.2.1.2-2 (a): Channel allocation in the time domain in multiple of 6 symbols
(Single UE, single antenna transmission case)

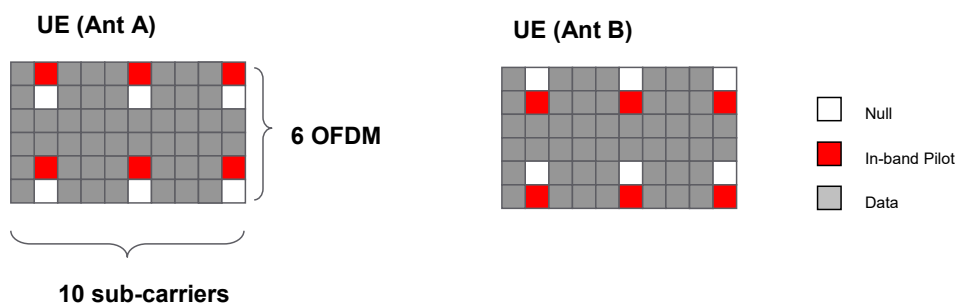


Figure 9.2.1.2-2 (b): Channel allocation in the time domain in multiple of 6 symbols
(Single UE, orthogonal pilot for multiple antenna transmission case)

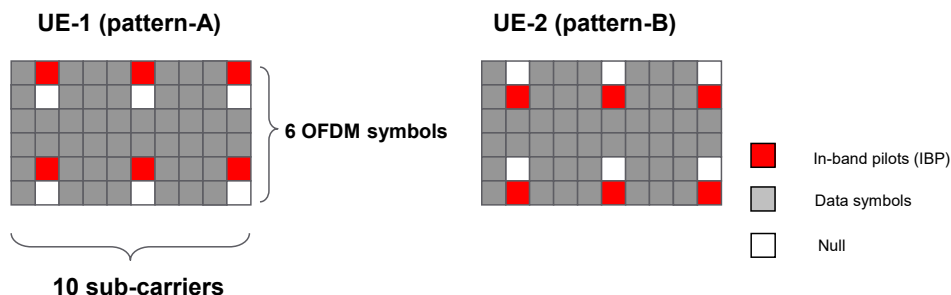


Figure 9.2.1.2-2 (c): Channel allocation in the time domain in multiple of 6 symbols
(Single antenna transmission, orthogonal pilots for virtual MIMO operation)

9.2.1.3 MIMO

The baseline antenna configuration for uplink single-user MIMO is two transmit antennas at the UE and two receive antennas at the Cell site.

The possibility for single-user higher-order uplink MIMO (more than two TX/RX antennas) should be considered.

The possibility for SDMA should also be considered. A specific example of SDMA corresponds to a (2x2) virtual MIMO, where two UEs, each of which transmitting on a single antenna, share the same time and frequency resource allocation. These UEs apply mutually orthogonal pilot patterns in order to simplify Cell site processing (cancellation). Note that from the UE perspective difference between (2x2) virtual MIMO and single antenna transmission is only the use of a pilot pattern allowing for “pairing” with another UE.

9.2.1.4 Peak to Average Power Ratio (PAPR) and its Reduction

OFDMA based UL transmission will lead to higher PAPR than the single carrier transmission schemes, the level of increase being dependent on the number of used sub-carriers and/or presence of out of band pilots for the support of frequency based scheduling. However, several digital processing based PAPR reduction techniques can be employed to mitigate the higher PAPR for the OFDMA UL.

9.2.1.4.1 Tone reservation PAPR reduction method

In Tone Reservation (TR) method [x], both transmitter and receiver agree on reserving a subset of tones \mathcal{R} for generating PAPR reduction signals.

Assuming total of N available tones and K tones are reserved. Let \mathbf{X} be frequency-domain data signal and $\mathbf{C} = [C_0, C_1, \dots, C_{K-1}]$ be a code on subset \mathcal{R} . The goal of TR method is to find the optimum code value \mathbf{C} so that:

$$\min_{\mathbf{c}} \|\mathbf{x} + \mathbf{c}\|_{\infty} = \min_{\mathbf{c}} \|\mathbf{x} + \hat{\mathbf{Q}}\mathbf{C}\|_{\infty} < \|\mathbf{x}\|_{\infty} \quad (9.2.1-1)$$

where: \mathbf{x} is the time-domain signal of \mathbf{X} ,

$\hat{\mathbf{Q}}$ is a $N \times K$ sub-matrix of \mathbf{Q} ,

\mathbf{Q} is the $N \times N$ inverse DFT matrix,

and $\|\mathbf{v}\|_{\infty}$ is the ∞ norm of \mathbf{v} .

In [x], a simple gradient algorithm with fast convergence is proposed. The overall TR iterative algorithm is simply:

$$\mathbf{x}^{i+1} = \mathbf{x}^i - \mu \cdot \sum_{|x_n^i| > A} \alpha_n^i \mathbf{p}_n \quad (9.2.1-2)$$

where: i is the iteration index;

μ is the updating step size;

n is the index for which sample x_n is greater than the clipping threshold;

$$\alpha_n^i = x_n^i - A \cdot \exp(j \cdot \text{angle}(x_n^i)); \quad (9.2.1-3)$$

and \mathbf{p}_n is called peak reduction kernel vector. The kernel is a time domain signal that is as close as possible to the ideal impulse at the location where the sample amplitude is greater than the predefined threshold. This way the peak could be cancelled as much as possible without generating secondary peaks. \mathbf{p}_n is derived from original kernel \mathbf{p}_0 through right circle shifting (by $n-1$ samples). The original kernel \mathbf{p}_0 can be calculated using 2-norm criteria and is given by the following formula:

$$\mathbf{p}_0 = \frac{\sqrt{N}}{K} \hat{\mathbf{Q}} \mathbf{1}_K \quad (9.2.1-4)$$

$\mathbf{1}_K$ is a vector of length K with all one elements.

In an example of the improved tone reservation with reduced complexity all tones except guard band [y] are used to calculate an original kernel. Then, α combined with μ is quantified to form derived reduction kernels. The phase is divided equally into s parts. And the amplitude is divided into t parts represented by some special values according to different FFT size and step length. For example, if FFT size is 1024, the phase is divided equally into six parts represented by $\pm\pi/6, \pm\pi/2, \pm5\pi/6$ and the amplitude can be chosen among 0.01, 0.04, 0.08, 0.12, 0.16. Thus only 30 peak reduction kernels need to be stored.

In order to reduce the computation load, only choose fixed number of peaks to be cancelled in one iteration instead of all the peaks that satisfies $|x_{n_i}| > A$.

The Steps of the improved TR method with reduced complexity is described below:

- Off line computation:
 1. Calculate the original kernel vector \mathbf{p}_0 based on 2-norm criteria, which is the IFFT of $\mathbf{1}_K$ (all tones except guard band);
 2. Quantify the original kernel to get derived kernels and store them in advance.
- Online iterations: The algorithm is based on each input OFDM symbol.
 1. Select the target PAPR value and corresponding threshold A ;
 2. Initially, set $\mathbf{x}^0 = \mathbf{x}$;
 3. Find fixed number of samples (in order) with locations n_i in which $|x_{n_i}| > A$;
 4. If all samples are below the target threshold, transmit \mathbf{x}^i . Otherwise, search among the derived kernels (stored in advance) to find matched ones according to Equation 3 and right circle shift them by n_i samples;
 5. Update \mathbf{x}^i according to Equation 2;
 6. Repeat step 3 to step 5 until i reaches maximum iteration limit. Transmit final \mathbf{x}^i .

9.2.1.4.2 Circulated clipping and filtering

Clipping is a simple method for PAPR reduction. In order to reduce PAPR meanwhile keep the spectrum characters of the signal, circulated clipping and filtering can be used [1].

Let $x(n)$ stands for transmitted signals without clipping, $y(n)$ stands for signals after clipping, and A is the threshold for clipping which is related to clipping ratio. One of clipping criterions is as the following equation.

$$y(n) = \begin{cases} \frac{A}{\sqrt{|x(n)|^2}} x(n), & \text{if } |x(n)|^2 > A^2 \\ x(n), & \text{if } |x(n)|^2 \leq A^2 \end{cases} \quad (9.2.1-5)$$

To suppress out-of-band leakage caused by clipping, filtering has to be added. Since filtering causes re-growth to PAPR, clipping and filtering are repeated in circles for times to depress the PAPR, meanwhile reduce out-of-band leakage to an acceptable degree. The principle of circulated clipping and filtering is given in Figure 9.2.1.4.2-1.

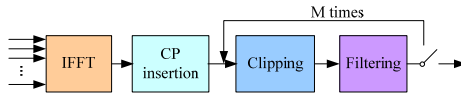


Figure 9.2.1.4.2-1 Circulated clipping and filtering

9.3 MC-WCDMA (FDD)

9.3.1 High level principles

This structure prioritizes spectrum compatibility, that is ability for legacy UE and evolved UTRA UEs to co-exist in the same spectrum allocation. The baseline structure, numerology and procedures should be the same as those defined for UTRA-FDD E-DCH with a 2 ms TTI; in particular:

- Frequency reuse 1

- Node-B scheduling
- Adaptive modulation and coding
- Intra and inter Node-B macro diversity

should be supported. This should be achieved without tight inter-site synchronisation.

The following additions to the baseline multiple access structure should be considered:

- Enhanced MAC/RLC in support of simultaneous reception from multiple carriers (up to 20 MHz).
- Enhanced uplink control structure and procedures in support of HS-DSCH and E-DCH operation with variable symmetric and asymmetric bandwidth allocations.
- Added support for 0.96 and possibly 1.92 Mcps numerology.
- Support for higher order modulation such as 16-QAM.
- Reduced uplink HARQ delay budget.

The system operation should rely on the definition of new E-DPDCH demodulation performance requirements based on the following Node B receiver techniques:

- Pilot and data interference cancellation.
- 2 and 4 antenna receive diversity.

9.3.2 Basic Transmission Scheme

This section goes over the specifics for a MC-WCDMA operation on the UL. Section 7.2.2.2 introduces operation over a 1.25MHz bandwidth by means of a low chip rate version of UTRA FDD (WCDMA LCR in the sequel). WCDMA LCR operation is based on direct sequence spreading over 1.25MHz.

The concepts presented are valid for multi-carrier operation based on the 5MHz system (UTRA FDD) as well as the 1.25MHz system (WCDMA LCR) or a 5MHz/1.25MHz hybrid multi-carrier system.

9.3.2.1 Definitions

Refer to section 7.2.2.1 for definitions relevant for EUTRA operation based on MC-WCDMA multi-carrier operation.

9.3.2.2 Assumptions for MC-WCDMA operation in UL

Only the HSUPA channels are eligible to be configured in a multi-carrier fashion i.e., a given UE will transmit information onto one or more than one carrier.

The timing of the PHY channels for *paired carriers* shall be no different than for a single carrier system where the timing of the UL channels is always referenced to the timing of associated DL channels (see 25.211 for a complete reference).

The timing of the PHY channels for *unpaired carriers* is explicitly covered in this Technical Report.

Multi-Carrier transmission characteristics:

- One cell is the serving E-DCH for all carriers supported by a given UE.
- HARQ PHY re-transmissions on UL takes place at the same carrier as for the first transmission.

Figure 9.3.2.2-1 is a block diagram depicting multi-carrier operation. Each of the colors represents a different UL carrier. Note that the PHY channels in squared brackets are just transmitted if associated downlink carrier is configured.

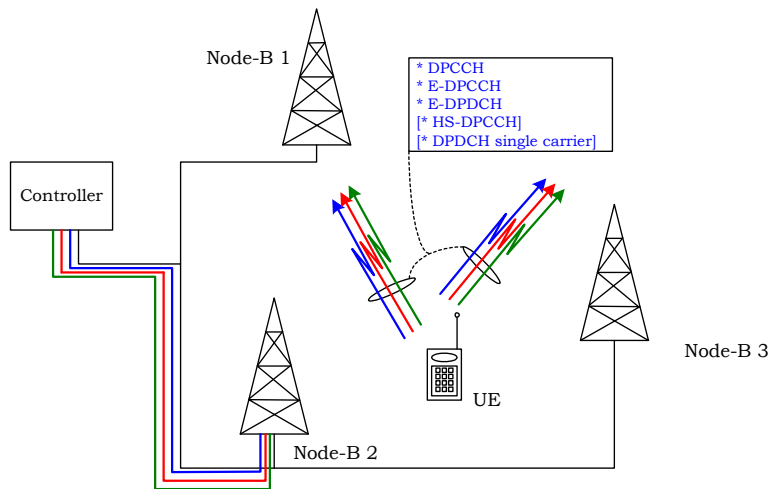


Figure 9.3.2.2-1. Block diagram for multi-carrier operation

9.3.2.3 UL Single-carrier PHY Channels

From the UE viewpoint, the system is accessed by way of the anchor carrier. In turn, the UE shall expect reception of the corresponding AICH (Access Indicator Channel) at the carrier associated with the one used for transmission of the PRACH. For DCH transmission, the UE is expected to use at most one carrier. Multi-carrier transmission is limited to the E-DCH.

9.3.2.4 UL Multi-Carrier PHY Channels

- Table 9.3.2.4-1 shows the data-payload channels:

Table 9.3.2.4-1. Data-payload Multi-carrier UL PHY channels

Channel	Num carriers
E-DPDCH	M

- Table 9.3.2.4-2 shows the control/supporting channels

Table 9.3.2.4-2. Control/supporting Multi-carrier UL PHY channels

Channel	Num required channels	Rationale
DPCCH	M	Phase reference (Pilot bits) for the M uplink carriers and TPC commands for DL power control the M downlink F-DPCHs.
E-DPCCH	M	Just transmitted when associated E-DPDCH channel is active.
HS-DPCCH	N	ACK/NACK and CQI information for the N downlink carriers

9.3.2.4.1 N/M Asymmetry considerations

The following observations can be made for the different N and M relative values.

- **M=N:** All the UL carriers have an associated DL carrier and vice-versa. PHY procedures for this case (i.e., Power Control, synchronization, HS-DSCH and E-DCH related procedures...) are no different than those for the single carrier case.
- **M>N:** Just the N paired carriers will carry the HS-DPCCH and the TPC commands for the N downlink carriers. Therefore, there will be (M-N) uplink DPCCH with no need for DL power control TPC commands.
- **M<N:** There are (N-M) downlink unpaired carriers. Therefore, besides the M paired carriers carrying HS-DPCCHs, the ACK/NACK and CQI information of (N-M) unpaired DL carriers will have to be conveyed from the UE to the E-UTRAN in some way. All the M downlink (F-)DPCHs are power controlled by the paired carriers. The proposed method to convey this additional control information is presented below.

To convey the HSDPA feedback information (i.e., ACK/NAK channel and CQI channel) of the (N-M) unpaired DL carriers is to code division multiplex (N-M) additional HS-DPCCHs within the M uplink carriers.

Doing this code division multiplexing requires the definition of the channelization code to be used by the additional HS-DPCCHs within a carrier. For the single carrier system, 25.213 specifies the SF 256 channelization code and the quadrature phase (depending on the number of DPDCHs configured) to be used by the only HS-DPCCH that may be transmitted at a UE. Therefore, 25.213 would have to further define the channelization code and the quadrature phase to be used by the additional HS-DPCCHs.

The additional HS-DPCCHs themselves would be no different to the HS-DPCCHs of the paired frequencies or the HS-DPCCH of the current single carrier system. The timing of these additional channels would be tied to the associated downlink HS-PDSCH.

As a general rule, in order to limit the impact on peak-to-average of the transmit waveform with an additional code channel, the (N-M) additional HS-DPCCHs would have to be spread across the M uplink carriers as much as possible.

In a similar way as Table 0 in 25.213, the following table summarizes the maximum number of simultaneous uplink dedicated PHY channels configurable at a given carrier.

Table 9.3.2.4.1-1. Maximum number of simultaneous uplink dedicated channels for different M:N carrier asymmetries

M:N Asymmetry	DPCCH	HS-DPCCH	E-DPCCH	E-DPDCH
1:1	1	1	1	4
1:2	1	2	1	3
1:3	1	3	1	2
1:4	1	4	1	1

As seen in Table 9.3.2.4.1-1, the maximum number of code channels allowed within one carrier is no more than the current maximum number of code channels allowed in Table 0 of 25.213.

Observations:

- There is one HS-DPCCH code channel for each HS-DPCCH corresponding to a downlink unpaired carrier.
 - First row in the table above is no different to the no-DPDCH configuration in Table 0 of 25.213.

- Note that the HS-PDSCHs are not power controlled. The TPC bits in the uplink DPCH power control the downlink (F-)DPCH. Power control of the HS-SCCH and the DL E-channels may be based on the CQI reports by the UE for each of the DL carriers.

9.3.3 Physical Layer Procedures

9.3.3.1 PHY channels timing considerations

As stated before, the timing of PHY channels for symmetric, i.e., $N = M$, multi-carrier configurations is such that each carrier complies with the timing requirements set forth in 25.211.

This section covers the timing specifics for asymmetric, i.e., $N \neq M$ multi-carrier configurations.

In the $N > M$ case, there are $(N-M)$ downlink unpaired carriers. The timing corresponding to the $(N-M)$ additional HS-DPCHs in the uplink is referenced to the timing of the associated downlink HS-DPCHs and therefore, it is well defined.

In the $N < M$ case, the timing of the PHY channels in the $(M-N)$ unpaired uplink carriers i.e., DPCH and E-DPCH timing, is well defined as it is referenced to $(M-N)$ additional (F-)DPCH allocated within the N downlink carriers. Note that for this case, the timing of each of the unpaired UL carriers is referenced to one of the N downlink carriers (the one with the associated (F-)DPCH).

9.3.3.2 Power Control: UL PC

Section 7.2.2.5 covers the DL multi-carrier channels and therefore the (F-)DPCHs carrying the power control commands for the UL.

As indicated in section 7.2.2.5, for each of the possible N/M relative values:

- $N=M$: each DL carrier has its associated UL carrier and vice-versa. Therefore, the N (F-)DPCH channels will power control the N uplink DPCHs.
- $N>M$: there are M necessary (F-)DPCHs that power control the M uplink DPCHs. Just the paired carriers carry the UL TPC commands over the respective F-DPCH.
- $N<M$: the (F-)DPCHs in the N paired carriers will power control the uplink DPCHs in those carriers. In addition, each cell in the UE's active set needs to allocate $(M-N)$ additional (F-)DPCHs within the N downlink carriers to perform power control of the uplink DPCH of the $(M-N)$ uplink unpaired carriers.

9.3.3.3 Random Access Procedure

There should be no difference in the random access procedure for a multi-carrier system as the initial system access is performed on a single carrier and the addition of carriers is considered to be a dedicated channel establishment or reconfiguration.

9.3.3.4 E-DCH Related Procedures

Transmission of E-DCH related channels is covered in section 7.2.2.5 for the DL (i.e., E-HICH, E-RGCH and E-AGCH) and section 9.3.2.4 for the UL (i.e., E-DPCH and E-DPDCH).

For each of the possible N/M relative values:

- $M=N$: each UL carrier has its associated DL carrier and vice-versa. Therefore, the M downlink E-HICH, E-RGCH and optionally E-AGCH will control the corresponding M uplink E-DPCHs.
- $M>N$: the E-HICH, E-RGCH and optionally E-AGCH in the N paired carriers will control the uplink E-DPCHs in those carriers. In addition, each cell in the UE's active set needs to allocate $(M-N)$ additional E-HICH, E-RGCH and optionally E-AGCH within the N downlink carriers to control the uplink E-DPCH of the $(M-N)$ uplink unpaired carriers. How that additional information is conveyed is subject to different options covered in section 7.2.2.5.

- **M<N**: the E-HICH, E-RGCH and optionally E-AGCH in the M paired carriers will control the uplink E-DPCHs in those carriers.

9.3.3.4.1 E-DPCH Retransmission on Multi-Carrier system

Operation in the multi-carrier system shall guarantee PHY HARQ retransmissions on the carrier that was used for the first transmission.

9.3.4 Physical layer measurements

9.3.4.1 Node B measurements

The Node B measurements for the MC-WCDMA based proposal are the same as those defined in section 5.2 of 25.215.

9.4 MC-TD-SCDMA (TDD)

9.4.1 Basic transmission scheme

For UL MC TD-SCDMA, a carrier with a wide bandwidth needs to be divided into several narrower sub-carriers and the adjacent sub-carriers do not overlap with each other. Each sub-carrier uses TDMA and CDMA techniques to identify the different users. According to the service's need, the same user can occupy one or several sub-carriers.

For the DL multiple access, the bandwidth of each downlink sub-carrier will be allocated as 1.6 MHz.

9.4.1.1 Modulation scheme

The uplink supports QPSK and 16QAM modulation schemes.

9.4.1.2 Multiplexing including pilot structure

9.4.1.3 Channel Coding and physical channel mapping

Convolution coding and Turbo coding can be considered for MC TD-SCDMA. Each coding scheme has its own characteristic.

9.4.1.4 MIMO and beamforming

The baseline antenna configuration for uplink MIMO is two transmit antennas at the UE, and two receive antennas at the Cell site. The possibility for more receive antennas should also be considered.

The antenna configuration for uplink transmit diversity (beamforming) is one or two transmit antennas at the UE, and the number of receive antennas from four to eight at the Cell site.

9.4.2 Physical channel procedure

9.4.2.1 Random access procedure

9.4.2.2 Scheduling

9.4.2.3 Link adaptation

Using AMC to adjust the modulation and coding rate, adaptive link technologies improve the performance of system.

9.4.2.4 Power control

The open-loop and close-loop power control are supported against deep fading, eliminating near-far effect, and fighting multiple access interference.

9.4.2.5 HARQ

Incremental Redundancy (IR) should be used for uplink HARQ. Note that Chase combining is a special case of IR

9.4.2.6 Uplink timing control

10 Evaluation of techniques for evolved UTRA UL

10.1 Performance evaluation

Note: absolute results shown in the respective sections should not be compared as the set of assumptions used to derive these respective results may differ.

10.1.1 Evaluation against reference

This section provides initial results of different E-UTRA uplink proposals, comparing with the baseline reference case defined in [4]:

- WCDMA Release-6
- 1 Transmit antenna at the UE
- 2 Receive antennas at the Node B
- Rake receiver
- 5 MHz transmission bandwidth

Results are normalized to bit per second per Hertz.

10.1.1.1 MC-WCDMA based evolved UTRA UL

The results presented in Table 10.1.1.1-1 are based on the uplink proposal described in section 9.3 and cases defined in Table A.2.1.1-1 except for the bandwidth which has been set to 5 MHz. The results are based on full buffer traffic models and proportional fair scheduler and compare the reference case and a receiver with successive interference cancellation (SIC); the system operating point is at IOT = 4.5 dB.

Table 10.1.1.1-1: Full buffer, 2Rx

Case	Speed [km/h]	Reference (WCDMA 2 Rx - MF) [b/s/Hz]	(MC-)WCDMA 2 Rx – SIC [b/s/Hz]	% w.r.t reference
1	3	0.33	0.64	+ 94%
2	30	0.32	0.72	+ 125%
3	3	0.32	0.72	+ 125%
4	3	0.32	0.64	+ 100%

10.1.1.2 OFDMA based evolved UTRA UL

The results presented in Table 10.1.1.2-1 are based on uplink proposal described in section 9.2 and cases defined in Table A.2.1.1-1. The results are based on full buffer traffic models and proportional fair scheduler; the system operation point is IOT=4.5 dB.

Table 10.1.1.2-1: Full buffer, 2 Rx

Case	Speed [km/h]	Reference (WCDMA 2 Rx - /MF) [b/s/Hz]	OFDMA 2 Rx Orthogonal [b/s/Hz]	% w.r.t reference
1	3	0.33	0.68	106%
2	30	0.32	0.68	113%
4	3	0.32	0.70	119%

10.1.1.3 Evaluation of SC-FDMA based evolved UTRA UL

The evaluation presented in Table 10.1.1-1 is based on the case 3 defined in Table A.2.1.1-1. The WCDMA reference results that has been obtained with 5 MHz bandwidth (but scaled for fair comparison for bits/Hz/MHz). The results are based on full buffer traffic models and proportional fair scheduler and compare matched filter receiver WCDMA reference case (with E-DCH) and a SC-FDMA receiver with only single user per frequency resource and blind interference coordination at cell level and slow power control. The higher WCDMA reference value is the same as the WCDMA reference simulation result shown in section 10.1.1.1). The reference with lower capacity is based on result in [3GPP TR 25.896.] with higher inter-site distance (2800 M) but no 20 dB penetration loss.

Table 10.1.1.3-1: Full buffer, 10 MHz, 2Rx, Average Capacity

Case	Speed [km/h]	Reference (WCDMA 2 Rx - /MF) [b/s/Hz]	SC-FDMA 2 Rx [b/s/Hz]	% w.r.t reference
3	3	0.26 to 0.32	0.78	+ 143% to 200%

The case in Table 10.1.1.3-2 is the cell edge case (taken from the same simulation run by looking the 5% CDF as in Table 10.1.1.3-1) with the same proportional fair scheduler and interference coordination over the 10 MHz bandwidth. The WCDMA reference gain obtained with 5 MHz bandwidth from [3GPP TR 25.896] with no additional penetration loss but higher inter-site distance and scaled for bits/MHz/cell for comparison (lack of the 20 dB penetration loss with WCDMA will more than compensate the longer inter-site distance in the reference case).

Table 10.1.1.3-2: Full buffer, 10 MHz, 2Rx, 5% CDF Capacity (cell edge)

Case	Speed [km/h]	Reference (WCDMA 2 Rx - /MF) [b/s/Hz]	SC-FDMA 2 Rx [b/s/Hz]	% w.r.t reference
3	3	0.026	0.087	+ 234%

10.1.2 Evaluation between evolved UTRA UL proposals

The section provides initial results comparing different E-UTRA uplink proposals.

10.1.2.1 Comparison between MC-WCDMA and OFDMA

The comparison presented in Tables 10.1.2.1-1 is based on results provided in section 10.1.1.1 and 10.1.1.2. The results are based on full buffer traffic models and proportional fair scheduler and compare orthogonal OFDMA based system with MC-WCDMA using a successive interference cancellation receiver; both operate at IOT=4.5 dB.

Table 10.1.2.1-1: Full buffer, 2 Rx

Case	Speed [km/h]	MC-WCDMA 2 Rx - SIC [b/s/Hz]	OFDMA 2 Rx Orthogonal [b/s/Hz]	% w.r.t MC-WCDMA 2 Rx - SIC
1	3	0.64	0.68	+ 6%
2	30	0.72	0.68	- 6%
4	3	0.64	0.70	+ 9%

The comparison presented in Table 10.1.2.1-2 assume OFDMA based system operated in non orthogonal manner (i.e. using spatial multiplexing) with MC-WCDMA using a successive interference cancellation receiver; both operate at IOT = 4.5 dB. Note that user separation in case of MC-WCDMA is by means of SIC while user separation in case of (non-orthogonal) MIMO is by means of less complex LMMSE, and can be further improved with SIC.

Table 10.1.2.1-2: Full buffer, 4 Rx

Case	Speed [km/h]	MC-WCDMA 4 Rx - SIC [b/s/Hz]	OFDMA 4 Rx (LMMSE)– Non Orthogonal [b/s/Hz]	% w.r.t MC-WCDMA 4 Rx - SIC
1	3	1.32	1.18	- 11%
2	30	1.48	1.16	- 22%
4	3	1.32	1.18	- 11%

10.1.2.2 Comparison between SC-FDMA and OFDMA

The initial comparison of SC-FDMA vs OFDMA for the uplink is summarized in Table 10.1.2.2-2, where the sector throughput of SC-FDMA and OFDMA are given for different inter-site distances. Full buffers, slow power control with 20 dB SNR target, and round robin scheduling was assumed. Note that results in section 10.1.1.1, 10.1.1.2 and 10.1.1.3 assume proportional fair scheduler.

The remaining simulation assumptions are summarized in Table 10.1.2.2-1.

Table 10.1.2.2-1: Scenarios used in Table 10.1.2.2-2

Scenario	CF [GHz]	Ploss [dB]	Speed [km/h]	BW [MHz]	Hybrid ARQ	Max PA output power (including back off)
A (case 1, 3)	2	20	3	10	No	24 dBm (SC, QPSK) 23.4 dBm (SC, 16QAM) 21.6 dBm (OFDMA)
B (case 1)					Chase	21 dBm (SC) 19 dBm (OFDMA)

Table 10.1.2.2-2: Sector throughput for SC-FDMA and OFDMA

Scenario	ISD [m]	Average Sector Throughput [b/s/Hz]		SC-FDMA gain vs. OFDMA
		SC-FDMA	OFDMA	
A	500	0.77	0.73	6%
B	750	0.69	0.65	6%
B	1000	0.52	0.48	9%
A	1732	0.46	0.41	10%
A	2800	0.24	0.21	13%

10.1.2.3 Evaluation of Virtual MIMO

The virtual MIMO has been studied for both OFDMA and SC-FDMA, and the results from the more detailed OFDMA studies are presented in Table 10.1.2.3-1 (initial results) is based on case 1 and case 2 defined in Table A.2.1.1-1 except for the channel model PA and VA. The results are based on full buffer traffic models and two virtual MIMO scheduling [3]; random user pairing scheduling (RPS) and orthogonal pairing scheduling (OPS). OFDMA based system operated in orthogonal manner is compared with systems operated in non orthogonal manner (i.e. using spatial multiplexing).

Table 10.1.2.3-1: OFDMA Full buffer, 10 MHz, 2 Rx

Case	Speed [km/h]	OFDMA 2 Rx Orthogonal [b/s/Hz]	Virtual MIMO RPS [b/s/Hz]	Virtual MIMO OPS [b/s/Hz]	% OPS w.r.t OFDMA 2 Rx Orthogonal
1	3	0.64	0.65	0.86	+33%
2	30	0.67	0.68	0.87	+28%

10.2 Analysis of UE complexity

10.3 Analysis of Node B impacts

11 UE capabilities

11.1 UE bandwidth capabilities

11.1.1 Downlink bandwidth capabilities

It is assumed that *all* UEs have a reception-bandwidth capability of at least 10 MHz implying that all UEs can receive all transmission bandwidths specified in Table 7.1.1-1 and 7.1.1-2 up to 10 MHz.

11.1.2 Uplink bandwidth capabilities

It is assumed that *all* UEs have a transmission-bandwidth capability of at least 10 MHz implying that all UEs support all transmission bandwidths specified in Table 9.1.1-1 up to 10 MHz.

11.2 UE antenna capabilities

11.2.1 Receive-antenna capabilities

11.2.2 Transmit-antenna capabilities

ANNEX A: Simulation scenarios

A.1 Link simulation Scenarios

A.1.1 Link simulation assumptions

The link level issues that need to be addressed in order to achieve alignment are given in the following Table. Simulation results should indicate the link to system level mapping methodology used and show supporting link results or give references to such material.

Table A.1.1-1 – Link Level issues for achieving alignment

Issues	Details
DL Modulation	QPSK, 16QAM, 64QAM
UL Modulation	BPSK, QPSK, 8PSK, 16QAM, [64QAM]
Coding for data channel and Mother code rate	Turbo, LDPC
Coding for control channel and Mother code	Turbo, Convolutional, other
DL Peak rates	
UL Peak rates	
Non-ideal receiver functions	Channel estimation,
Available Mappings	MIESM, EESM, ECM, QSA, AVI, etc Account for HARQ, IR, and MIMO

A.1.2 Maximum SNR per channel

For high SNR operation especially with high order modulation or MIMO schemes it will be important to understand practical apparatus impacts and this can be performed by addressing the following topics

Table A.1.2-1 – Maximum SNR limit dependencies

Issues	Details
EVM	
Phase and Doppler self interference	
Adjacent carrier interference	
UE A/D and baseband filtering	
Antenna front-to-back ratio	[20]dB
Non-ideal sector isolation	
Unrecovered power	

A.1.3 Multi-Antenna Link level channel models

For evaluating the performance of different multi-antenna techniques, relevant channel models that capture the spatial properties is important. The SCM [7] and its extension to wider bandwidth SCME provide such models for system level evaluations. Here the corresponding link level models are described.

4 different scenarios, SCM-A to D, are considered, see Table A.1.3-1, they represent a subset of “typical” antenna configurations and propagations scenarios.

Table A.1.3-1 – Representative cases

Name	Propagation scenario	BS arrangement	MS arrangement
SCM-A	Suburban Macro	3-sector, 0.5λ spacing	Handset, talk position
SCM-B	Urban Macro (low spread)	6-sector, 0.5λ spacing	Handset, data position
SCM-C	Urban Macro (high spread)	3-sector, 4λ spacing	Laptop
SCM-D	Urban Micro	6-sector, 4λ spacing	Laptop

Note that models SCM-C and SCM-D can also be used for evaluating laptops with two receive antennas. In this case, one should select the channel coefficients associated with one of the two dual-polarized antennas.

The multi-antenna channel model is a tapped delay line model with covariance matrices for describing the fast fading correlation and power distribution over transmit and receive antennas.

The total per-tap covariance matrix \mathbf{R}_{tap} is obtained from the Kronecker product of the polarization covariance matrix $\mathbf{\Gamma}$ and the Node B and UE spatial correlation matrices \mathbf{A} and \mathbf{B} , further weighted by the antenna gains at Node B and UE:

$$\mathbf{R}_{\text{tap}} = p_{\text{tap}} \cdot g_{\text{NodeB,tap}} \cdot g_{\text{UE,tap}} \cdot \mathbf{A} \otimes \mathbf{\Gamma} \otimes \mathbf{B}$$

where p_{tap} is the relative power of the tap, $g_{\text{NodeB,tap}}$ is the effective antenna gain at the Node B, $g_{\text{UE,tap}}$ is the

antenna gain at the UE, $\mathbf{A} = \begin{bmatrix} 1 & \alpha \\ \alpha^* & 1 \end{bmatrix}$ and $\mathbf{B} = \begin{bmatrix} 1 & \beta \\ \beta^* & 1 \end{bmatrix}$, \otimes denotes Kronecker multiplication.

To determine $\mathbf{\Gamma}$ unambiguously, the antenna polarization combination matrix is vectorized as $[P1_{\text{NodeB}}P1_{\text{UE}}, P2_{\text{NodeB}}P1_{\text{UE}}, P1_{\text{NodeB}}P2_{\text{UE}}, P2_{\text{NodeB}}P2_{\text{UE}}]$. Note that P1 and P2 refer respectively to vertical and horizontal UE polarizations (nominal orientation) and $\pm 45^\circ$ Node B polarizations.

For the 4 selected scenarios, SCM-A, SCM-B, SCM-C and SCM-D, the effective tap power that includes the effective antenna gains at Node B and UE is tabulated below

Table A.1.3-2 SCM-A (Suburban Macro, 3-sector, 0.5λ spacing, Handset, talk position)

Tap/mid-path	Delay [ns]	Power, P_{tap} [dB]	Node B spatial correlation, α	Polarization covariance matrix, $\mathbf{\Gamma}$, [4x4]			
1/1	0.0	0.00	$0.4783 + 0.8722i$	0.5953	-0.0858	0	0.2534
1/2	12.5	-2.22		-0.0858	0.5953	0.2534	0
1/3	25.0	-3.98		0	0.2534	0.2976	0.0429
2/1	137.5	-8.50	$0.4569 + 0.8836i$	0.2534	0	0.0429	0.2976
2/2	150.0	-10.72		0.6174	0.1139	0	0.0745
2/3	162.5	-12.48		0.1139	0.6174	0.0745	0
3/1	62.5	-7.28	$0.8407 + 0.5308i$	0	0.0745	0.3087	-0.0570
3/2	75.0	-9.50		0.0745	0	-0.0570	0.3087
				0.6550	0.0172	0	0.1887
				0.0172	0.6550	0.1887	0

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3/3	87.5	-11.26		0	0.1887	0.3275	-0.0086
				0.1887	0	-0.0086	0.3275
4/1	400.0	-8.45	0.8935 + 0.4359i	0.7153	-0.1054	0	0.1798
4/2	412.5	-10.67		-0.1054	0.7153	0.1798	0
4/3	425.0	-12.43		0	0.1798	0.3576	0.0527
				0.1798	0	0.0527	0.3576
5/1	1387.5	-14.65	0.9444 + 0.3103i	0.8460	-0.0531	0	0.0973
5/2	1400.0	-16.86		-0.0531	0.8460	0.0973	0
5/3	1412.5	-18.63		0	0.0973	0.4230	0.0265
				0.0973	0	0.0265	0.4230
6/1	2825.0	-26.43	0.9783 + 0.1763i	1	0	0	0
6/2	2837.5	-28.64		0	1	0	0
6/3	2850.0	-30.41		0	0	0.5	0
				0	0	0	0.5

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Total per-tap covariance matrix: $\mathbf{R} = 10^{P_{\text{tap}}/10} \cdot \begin{bmatrix} 1 & \alpha^* \\ \alpha & 1 \end{bmatrix} \otimes \mathbf{\Gamma}$ where the symbol \otimes denotes the Kronecker product.

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Table A.1.3-3 SCM-B (Urban Macro (low spread), 6-sector, 0.5λ spacing, Handset, data position)

Tap/mid-path	Delay [ns]	Power, P_{tap} [dB]	Node B _s spatial correlation, α	Polarization covariance matrix, $\mathbf{\Gamma}$ [4x4]			
1/1	0		0.4902 + 0.8656i	0.5953	0.1936	0	0.1834
1/2	12.5	0.00		0.1936	0.5953	0.1831	0
1/3	25.0	-2.22		0	0.1831	0.2976	-0.0968
		-3.98		0.1831	0	-0.0968	0.2976
2/1	362.5	-	0.5521 + 0.8274i	0.6134	0.2430	0	0.1106
2/2	375.0	1.17		0.2430	0.6134	0.1106	0
2/3	387.5	-3.39		0	0.1106	0.3067	-0.1215
		-5.15		0.1106	0	-0.1215	0.3067
3/1	250.0	-2.65	0.5902 + 0.8006i	0.6090	0.1197	0	0.2282
3/2	262.5	-4.86		0.1197	0.6090	0.2282	0
3/3	275.0	-6.62		0	0.2282	0.3045	-0.0598
				0.2282	0	-0.0598	0.3045
4/1	1037.5	-13.57	-0.2706 + 0.9587i	0.6430	0.2501	0	0.0514
4/2	1050.0	-15.79		0.2501	0.6430	0.0514	0
4/3	1062.5	-17.55		0	0.0514	0.3215	-0.1250
				0.0514	0	-0.1250	0.3215
5/1	2725.0	-22.40	-0.4100 + 0.9082i	0.6935	0.0778	0	-0.1912
5/2	2737.5	-24.62		0.0778	0.6935	-0.1912	0
5/3	2750.0	-26.38		0	-0.1912	0.3468	-0.0389
				-0.1912	0	-0.0389	0.3468
6/1	4600.0	-28.05	-0.5814 + 0.8099i	0.7535	0.1275	0	-0.1025
6/2	4612.5	-30.26		0.1275	0.7535	-0.1025	0
6/3	4625.0	-32.03		0	-0.1025	0.3768	-0.0638
				-0.1025	0	-0.0638	0.3768

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Total per-tap covariance matrix: $\mathbf{R} = 10^{P_{\text{tap}}/10} \cdot \begin{bmatrix} 1 & \alpha^* \\ \alpha & 1 \end{bmatrix} \otimes \mathbf{\Gamma}$ where the symbol \otimes denotes the Kronecker product

Table A.1.3-4 SCM-C (Urban Macro (high spread), 3-sector, 4λ spacing, Laptop)

Tap/mid-path	Delay [ns]	Power, P _{tap} [dB]	Node B spatial correlation α UE spatial correlation β	Polarization covariance matrix, Γ _p [4x4]			
1/1	0		-0.4616 + 0.5439i	0.5953	0.4047	0	0
1/2	12.5	0.00	0.0225 - 0.0595i	0.4047	0.5953	0	0
1/3	25.0	-2.22		0	0	0.5953	-0.4047
		-3.98		0	0	-0.4047	0.5953
2/1	362.5	-1.86	-0.2806 + 0.6476i	0.6134	0.3866	0	0
2/2	375.0	-4.08	0.0088 + 0.0602i	0.3866	0.6134	0	0
2/3	387.5	-5.84		0	0	0.6134	-0.3866
				0	0	-0.3866	0.6134
3/1	250.0	-1.08	-0.1136 - 0.6818i	0.6090	0.3910	0	0
3/2	262.5	-3.30	0.0307 + 0.0555i	0.3910	0.6090	0	0
3/3	275.0	-5.06		0	0	0.6090	-0.3910
				0	0	-0.3910	0.6090
4/1	1037.5	-9.08	-0.6944 + 0.5043i	0.6430	0.3570	0	0
4/2	1050.0	-11.30	-0.0244 - 0.0028i	0.3570	0.6430	0	0
4/3	1062.5	-13.06		0	0	0.6430	-0.3570
				0	0	-0.3570	0.6430
5/1	2725.0	-15.14	-0.4072 + 0.5626i	0.6935	0.3065	0	0
5/2	2737.5	-17.36	0.0828 - 0.2378i	0.3065	0.6935	0	0
5/3	2750.0	-19.12		0	0	0.6935	-0.3065
				0	0	-0.3065	0.6935
6/1	4600.0	-20.64	-0.7753 + 0.1776i	0.7535	0.2465	0	0
6/2	4612.5	-22.85	0.4194 - 0.2429i	0.2465	0.7535	0	0
6/3	4625.0	-24.62		0	0	0.7535	-0.2465
				0	0	-0.2465	0.7535

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Total per-tap covariance matrix: $\mathbf{R} = 10^{P_{\text{tap}}/10} \cdot \begin{bmatrix} 1 & \alpha^* \\ \alpha & 1 \end{bmatrix} \otimes \mathbf{\Gamma} \otimes \begin{bmatrix} 1 & \beta^* \\ \beta & 1 \end{bmatrix}$ where the symbol \otimes denotes the

Kronecker product.

Table A.1.3-5 SCM-D (Urban Micro, 6-sector, 4λ spacing, Laptop)

Tap/mid-path	Delay [ns]	Power, P _{tap} [dB]	Node B spatial correlation α UE spatial correlation β	Polarization covariance matrix, Γ _p [4x4]			
1/1	0.0		-0.0907 + 0.1632i	0.5792	0.4208	0	0
1/2	12.5	0.00	0.0225 - 0.0595i	0.4208	0.5792	0	0
1/3	25.0	-2.22		0	0	0.5792	-0.4208
		-3.98		0	0	-0.4208	0.5792
2/1	287.5	-3.57	-0.0301 - 0.1586i	0.5792	0.4208	0	0
2/2	300.0	-5.79	0.0061 - 0.0051i	0.4208	0.5792	0	0
2/3	312.5	-7.55		0	0	0.5792	-0.4208
				0	0	-0.4208	0.5792
3/1	200.0	-29.05	-0.5144 - 0.3812i	0.5792	0.4208	0	0
3/2	212.5	-31.27	0.0297 - 0.0078i	0.4208	0.5792	0	0
3/3	225.0	-33.03		0	0	0.5792	-0.4208
				0	0	-0.4208	0.5792
4/1	662.5	-20.94	-0.1275 + 0.0979i	0.5792	0.4208	0	0
4/2	675.0	-23.15	-0.0244 + 0.0029i	0.4208	0.5792	0	0
4/3	687.5	-24.91		0	0	0.5792	-0.4208
				0	0	-0.4208	0.5792
5/1	812.5	-5.28	-0.0943 + 0.1609i	0.5792	0.4208	0	0

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$\frac{5}{2}$	825.0	-7.50	-0.0010 - 0.0061i	0.4208	0.5792	0	0
$\frac{5}{3}$	837.5	-9.26		0	0	0.5792	-0.4208
				0	0	-0.4208	0.5792
$\frac{6}{1}$	925.0	-26.96	$0.0505 + 0.2761i$	0.5792	0.4208	0	0
$\frac{6}{2}$	937.5	-29.18	$0.0080 - 0.0600i$	0.4208	0.5792	0	0
$\frac{6}{3}$	950.0	-30.94		0	0	0.5792	-0.4208
				0	0	-0.4208	0.5792

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Total per-tap covariance matrix: $\mathbf{R} = 10^{P_{\text{tap}}/10} \cdot \begin{bmatrix} 1 & \alpha^* \\ \alpha & 1 \end{bmatrix} \otimes \mathbf{\Gamma} \otimes \begin{bmatrix} 1 & \beta^* \\ \beta & 1 \end{bmatrix}$ where the symbol \otimes denotes the

Kronecker product.

A.2 System simulation scenario

A.2.1 System simulation assumptions

To facilitate evaluation of EUTRA and HSDPA/HSUPA (UTRA) the simulation assumptions are largely based on assumptions given in the previous HSDPA [2] and HSUPA [3] study items and reflect requirements in 25.913 [4]. Assumptions for reference system deployment and reference UE and Node-Bs along with channel and traffic models are given in the following sections. Scheduling and resource allocation as well as system and user performance metric assumptions are also included.

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A.2.1.1 Reference system deployments

A.2.1.1.1 Cell dimensions

A Macro-cell reference system deployment type is considered sufficient to characterize UTRA and EUTRA performance. The system simulation baseline parameters for the Macro-cell deployment model are given in Table A.2.1.1-23. The minimum set of simulation cases using assumptions in Table A.2.1.1-2-3 are given in Table A.2.1.1-1 along with additional assumptions related to carrier frequency (CF), Inter-site distance (ISD), operating bandwidth (BW), penetration loss (PLoss) and UE speed. Note that 100% of the users for a given simulation case are assigned the same 'PLoss' and speed.

The system simulation parameters for the micro cell scenario used for initial MIMO system level simulations are given in Table A.2.1.1-4. The minimum set of micro cell simulation cases are given in Table A.2.1.1-2.

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Table A.2.1.1-1 – UTRA and EUTRA simulation case minimum set

Simulation	CF	ISD	BW	PLoss	Speed
Cases	(GHz)	(meters)	(MHz)	(dB)	(km/h)
1	2.0	500	10	20	3
2	2.0	500	10	10	30
3	2.0	1732	10	20	3
4	0.9	1000	1.25	10	3

Other scenarios may, and higher velocities (e.g. 120km/h) shall be also verified.

Table A.2.1.1-2 EUTRA micro-cell simulation cases for MIMO

Simulation	CF	ISD	BW	PLoss	Speed
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Cases	(GHz)	(meters)	(MHz)	(dB)	(km/h)
Outdoor-to-outdoor	2.0	130	10	Na	3/30
Outdoor-to-indoor	2.0	130	10	Na*	3



* Penetration loss is included in the distance dependent pathloss model

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Table A.2.1.1-2-3 – Macro-cell system simulation baseline parameters

Parameter		Assumption
Cellular Layout		Hexagonal grid, 19 cell sites, 3 sectors per site
Inter-site distance		See Table A.2.1.1-1
Distance-dependent path loss		$L = I + 37.6 \log_{10}(R)$, R in kilometers $I = 128.1 - 2 \text{ GHz}$, $I = 120.9 - 900 \text{ MHz}$ [5][5]
Lognormal Shadowing		Similar to UMTS 30.03, B 1.4.1.4 [6][6]
Shadowing standard deviation		8 dB
Correlation distance of Shadowing		50 m (See D.4 in UMTS 30.03)
Shadowing correlation	Between cells	0.5
	Between sectors	1.0
Penetration Loss		See Table A.2.1.1-1 [11][11] [15][15]
Antenna pattern [4] (horizontal) (For 3-sector cell sites with fixed antenna patterns)		$A(\theta) = -\min \left[12 \left(\frac{\theta}{\theta_{3dB}} \right)^2, A_m \right]$ $\theta_{3dB} = 70 \text{ degrees}$, $A_m = 20 \text{ dB}$
Carrier Frequency / Bandwidth		See Table A.2.1.1-1
Channel model		Typical Urban (TU) early simulations Spatial Channel Model (SCM) later simulations
UE speeds of interest		3km/h, 30km/h, 120km/h, 350km/h
Total BS TX power (Ptotal)		43dBm – 1.25, 5MHz carrier, 46dBm - 10MHz carrier
UE power class		21dBm (125mW). 24dBm (250mW)
Inter-cell Interference ModelingModelling		UL: Explicit modelingmodelling (all cells occupied by UEs), DL: Explicit modelingmodelling else cell power = Ptotal
Antenna Bore-sight points toward flat side of cell (for 3-sector sites with fixed antenna patterns)		
Users dropped uniformly in entire cell		

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Minimum distance between UE and cell	≥ 35 meters [7]
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Table A.2.1.1-4 Micro-cell system simulation parameters for initial or early MIMO simulation results

Parameter		Assumption	
		Outdoors to indoors	Outdoors to outdoors
Cellular Layout		Hexagonal grid, 19 cell sites, 1 sectors per site	
Inter-site distance		See A.2.1.1-2	
Distance-dependent path loss		$L[dB] = 7 + 56 \log_{10}(d[m])$	$L[dB] = \begin{cases} 39 + 20 \log_{10}(d[m]) & 10m < d \leq 45m \\ -39 + 67 \log_{10}(d[m]) & d > 45m \end{cases}$
Lognormal Shadowing		Similar to UMTS 30.03, B 1.41.4 [6]	
Shadowing standard deviation		10 dB	10dB
Correlation distance of Shadowing		10 m	25 m
Shadowing correlation	Between cells	0.0	
	Between sectors	na	
Penetration Loss		Included in Distance dependent pathloss model	
Antenna pattern (horizontal) (For omni cell sites with fixed antenna patterns)		$A(\theta) = 1$	
Carrier Frequency		CF= 2GHz	
Channel model		According to Table A.2.1.2-1	
UE speeds of interest		3km/h	3km/h, 30km/h
Total BS TX power (Ptotal)		38 dBm – 10MHz carrier [7]	
UE power class		21dBm (125mW), 24dBm (250mW)	
Inter-cell Interference Modelling		UL: Explicit modelling (all cells occupied by Ues), DL: Explicit modelling else cell power = Ptotal	
BS prostitution in the middle of the hexagon			
Users dropped uniformly in entire cell			
Minimum distance between UE and cell		≥ 10 m (and minimum coupling loss of -53dB) The distance dependent pathloss + shadow fading is lower limited to free-space distance dependent pathloss	

A.2.1.1.2 Downlink and uplink numerology

TBD based on candidate technology.

A.2.1.2 Channel models

A.2.1.2.1 Multi-path channel models & early simulations

In order to simplify initial simulation work, and to facilitate the rapid generation of early results, the GSM Typical Urban channel model could represent a useful channel model. Alternatively, a set of ITU channel models could also be used. In order to keep the number of channel models to a minimum, the 6-ray Typical Urban channel model given first (1) [8f8, Section C.3.3] may be the best candidate for early simulations (see Table A.2.1.2-1) because of its larger delay spread. It is intended to use TU for early non-MIMO simulations for all bandwidth modes. Note for receiver/transmitter diversity and initial STC evaluation, there is less of a need for the SCM.

Table A.2.1.2-1 – Channel model for rapid generation of early simulations

Channel Model Target	Assumption
Channel model for initial or early simulations	Typical Urban (TU) for Micro, Macro cell
Channel model for initial or early simulations	Multi-Antenna Link level channel models (section A.1.3)

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A.2.1.2.2 Spatial channel model (SCM)

In later detailed simulations (per the RAN EUTRA work schedule), to accurately address Multi-Antenna subsystem (MAS) performance for EUTRA, the Spatial Channel Model (SCM) [7f7] is needed (see Table A.2.1.2.-2). The SCM accounts for transmitter and receive antenna correlation and more accurately reflects the likelihood of formulating multiple streams (spatial sub-channels) for certain MIMO schemes. The SCM is also needed for Beamforming and SDMA (or Spatial Multiplexing).

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A.2.1.2.2.1 SCM and extension to wider BW

The usage of SCM as currently defined in TR 25.996 for bandwidths above 5MHz is FFS. It is intended to use SCM for MIMO simulations up to 5MHz and use suitable channel models (e.g. SCM or modified SCM) for MIMO simulations for higher bandwidths.

Table A.2.1.2-2 – Channel model for later MIMO simulations in RAN1

Channel Model Target	Assumption
Channel model for later simulations in RAN1	

A.2.1.3 Traffic models

Proposed traffic models for evaluating EUTRA and UTRA performance are given in Table A.2.1.3-1. The traffic models are grouped in terms of Best Effort Packet Service type and Packet Service with Conversational Service (CS) like QoS type. It is expected to reuse HSDPA/HSUPA traffic models with detailed parameters FFS.

Table A.2.1.3-1 Traffic Models

Traffic Models	Model Applies to
Best Effort Packet Service	
FTP	DL or UL with TCP feedback

HTTP	DL with TCP feedback on UL
PS with CS like QoS	
VoIP	DL and UL
Streaming	DL and UL
Video Conferencing	DL and UL
Gaming	UL

A.2.1.3.1 Latency analysis

In order for latency to be fully and (parameters for latency evaluation) formally analyzed a UTRA and EUTRA delay model is needed. Such a model is needed for the ongoing work in RAN1 and RAN4. Also key protocol simulation models (e.g. TCP congestion, slow start, etc) should be detailed enough to reflect their impact on latency (e.g. ~~modeling~~modelling TCP ACKs on the uplink when ~~modeling~~modelling downlink packet transmissions).

A.2.1.4 System performance metrics

Performance metrics (user throughput, cell throughput, FER, etc) are described in [242] and [343] and can be reused for UTRA and EUTRA evaluation. It is important to ensure that SDMA and MIMO are properly handled in an uplink wrap around model. It is important to ensure that SDMA, MIMO, and macro-diversity schemes are properly handled for the downlink if only populating the centre cell site with users. Link budgets promote easier interpretation of system simulation results and it would be useful to include them along with simulation results and assumptions.

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A.2.1.5 Reference Release 6 (UTRA) UE

Reference UTRA UE parameters are given in Table A.2.1.5-1. Note a differential offset from maximum UE transmit power equivalent to $g = \text{MAX}(\text{Cubic Metric} - 1, 0)$ should be included in the system simulations for each uplink UTRA (HSUPA) transmitter configuration used. Cubic metric is defined in [949], [1040].

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Table A.2.1.5-1 –Reference UTRA UE parameters

Parameters	Model Assumptions
Receiver	Performance Type 1 (Rx Diversity)
Transmitter	1 Antenna
Antenna gain	0 dBi
Noise Figure	9dB
HSDPA UE Capability Category	14Mbps (15 codes) , Capability Category 10
HSUPA UE Capability Category	CC6: 2Mbps TTI=10ms, 5.76Mbps TTI=2ms
Multicast	S-CCPCH soft combining for multicast

A.2.1.6 Reference EUTRA UE

Reference EUTRA UE parameters are given in Table A.2.1.6-1. Note a differential offset from maximum UE transmit power equivalent to $g = \text{MAX}(\text{Cubic Metric} - 1, 0)$ should be included in the system simulations for each transmitter configuration used for a given EUTRA MA scheme. Hence, for each transmitter configuration the Cubic Metric [949], [1040] is computed and the maximum UE transmit power is reduced by g .

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Table A.2.1.6-1 – Reference EUTRA UE parameters

Parameters	Model Assumptions
Receiver	2 Antennas
Transmitter	1 Antenna
Antenna gain	0 dBi
Noise Figure	9 dB
MIMO	support for 2x2 downlink MIMO
Peak to Average/Cubic Metric	Should be specified based on MA used

A.2.1.7 Reference Release 6 (UTRA) Node-B

Reference UTRA Node-B parameters are given in Table A.2.1.7-1.

Table A.2.1.7-1 – UTRA Reference Node-B

Parameters	Model Assumptions
Node-B Transmitter	1 Antenna
Node-B Receiver	2 Antennas – Rake, Ideal antenna de-correlation 8 fingers assignable per UE
BS antenna gain plus cable loss	14 dBi for micro, macro cell case
Node-B HS-DSCH codes (N)	N = 15 – DPCH code overhead
Noise Figure	5 dB
Pilot channel power overhead (P_PILOT)	10% (CPICH)
Common channel power overhead (P_OVHD)	10% (SCH, P-CCPCH, S-CCPCH)
DL HSUPA channel power overhead (P_HSUPA)	[8]% (E-AGCH, E-RGCH, E-HICH)
Power available for HS-DSCH/HS-SCCH/DPCH	100% - P_PILOT - P_OVHD – P_HSUPA
HS-SCCH	Explicitly modeled modelled else 5% power overhead
DL DPCH (F-DPCCH or Assoc.)	Explicitly modeled modelled else 10% power overhead

A.2.1.8 Reference EUTRA Node-B

Reference UTRA Node-B parameters are given in Table A.2.1.8-1. Any additional support of number antennas beyond two (e.g. to support SDMA or Beamforming) at the Node-B is beyond what is given in the requirements document [44] and is FFS.

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Table A.2.1.8-1 EUTRA Reference Node-B

Parameters	Model Assumptions
Node-B Transmitter	2 Antennas
Node-B Receiver	2 Antennas
Noise Figure	5 dB
BS antenna gain plus cable loss	14 dBi for micro,macro cell case 6 dBi for micro cell case with omni-antennas (with cable losses included)
Pilot channel overhead	Total time and/or power resources dependent on MA and numerology are given or accounted for in simulation.
Control channel overhead	Total time and/or power resources dependent on MA given or accounted for in simulation (includes sync, paging, L1/2 signaling, resource allocation, HARQ feedback, etc)

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A.2.1.9 Scheduling & resource allocation

Various scheduling approaches will have performance and overhead impacts and will need to be aligned. Scheduling issues include support for conversational and streaming traffic and fairness in general.

A.2.1.9.1 Proportional fair or other scheduling

A description of scheduling and resource allocation schemes simulated should be provided. For frequency specific scheduling, the feedback approach, delay, and feedback error assumptions should also be indicated.

A.2.1.9.2 Fairness criteria

EUTRA and UTRA performance evaluation and comparison require that fairness be preserved or at least known in order to promote apple and apple (fair) comparisons. Fairness is defined as the normalized user packet call throughput CDF.

A.2.2 Multi-antenna subsystems

A.2.2.1 MIMO

In the evaluation of MIMO techniques for EUTRA MA candidates the following areas need to be aligned. It is necessary to provide non-MIMO performance as a benchmark before or along with MIMO performance. Specific MIMO schemes simulated for the work item phase should be accurately described.

Table A.2.2.1-1 – MIMO issues for achieving alignment

Issues	Details
Idealized generic MIMO model	
Non-ideal receiver issues	Non-ideal channel estimation, antennas (non-ideal patterns formed)
SNR estimation for LLR extraction	
MIMO antenna geometry	
MIMO feedback	Rate, delay, error
CQI feedback	Rate, delay, error

HARQ ACK/NACK	Error rates/probabilities
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A.2.2.2 SDMA/Beamforming

More than 2 EUTRA Node-B antennas are likely needed to evaluate SDMA and Beamforming. Defining reference EUTRA Node-B with 4 or more antennas is TBD.

A.2.3 System configuration and performance topics

A.2.3.1 Frequency re-use assessment

It is important to properly account for effects of 1x1 and 1x3 frequency reuse² on data channel performance and control channel reliability. Improvements from 1x3 should be characterized in terms of transmit power, coding gain differences, other cell interference, and loading.

A.2.3.2 Frame signaling reliability [TBD]

A.2.3.3 Macro diversity performance

It is key that macro diversity gain in the context of the new E-UTRA air interface is reassessed. Effects of macro diversity techniques (soft handoff, fast cell selection, multicast) should be evaluated with each traffic type and account for mobility. For example, it is important to account for a user that is not always attached to the best coverage cell due to delays in cell reselection.

A.2.3.4 Timing synchronization

Timing synchronization assumptions are important in determining guard interval requirements for unicast and broadcast modes. Such assumptions are FFS.

A.2.3.5 RACH channel performance [TBD]

A.2.4 Examples of Cell and User throughput evaluation

Two evaluation approaches are given. One approach is to load the UTRA and EUTRA systems to several different levels where at each level the 5% user throughput CDF value is computed. This allows the UTRA and EUTRA comparison based on two curves of load or sector throughput vs. 5% user throughput CDF. Another approach is to load each system up to a level corresponding to a user packet call throughput cdf outage (e.g. 2%) and then compare the corresponding 5% CDF user throughput values as well as the average cell and user throughputs.

² Frequency reuse of $a \times b$ where 'a' is site reuse and 'b' is sector reuse.

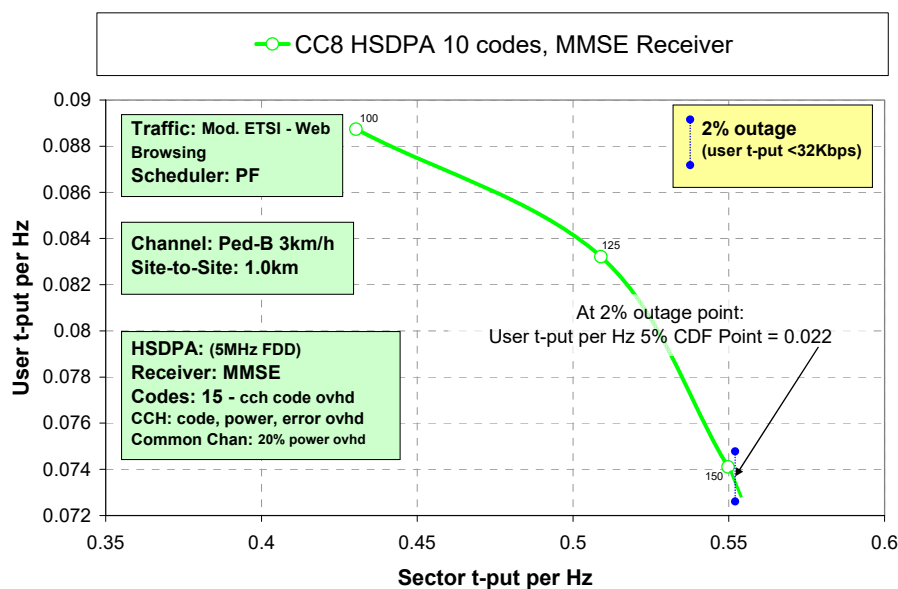


Figure A.2.4-1 – Example of User vs. Sector per Hz throughput with 5% CDF user throughput given at 2% outage point.

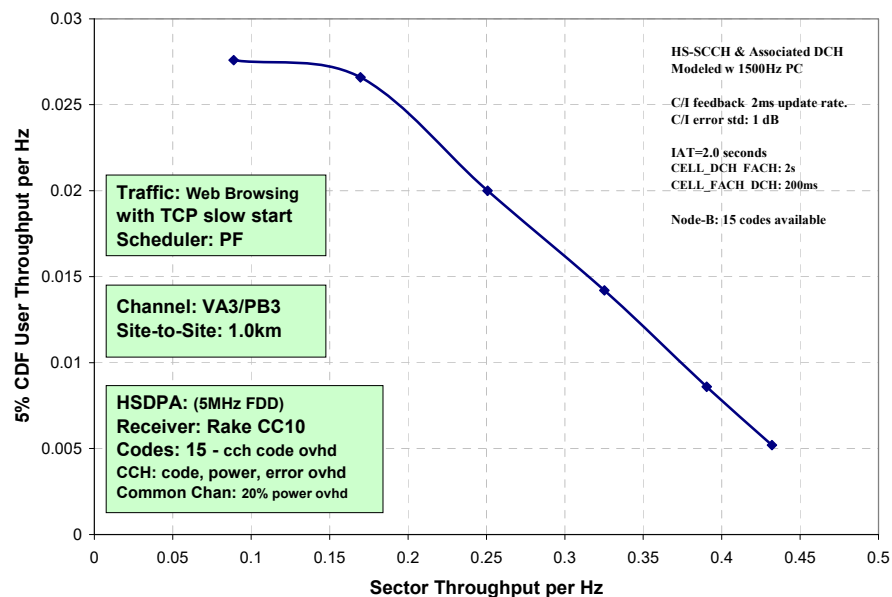


Figure A.2.4-2 – Example of 5% CDF User throughput vs. Sector throughput (per Hz)

ANNEX B: Change History

Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
4-2005	RAN1#40bis	R1-050372			Initial TR skeleton presented for approval		0.1.0
6-2005	RAN1#adhoc	R1-050682			Basic transmission schemes and simulation assumption		0.1.1
8-2005	RAN1#42	R1-050698			Editorial correction	0.1.1	0.1.2
8-2005	RAN1#42	R1-050975			Raised to v0.2.0 following presentation of v0.1.2 at RAN1#42	0.1.2	0.2.0
10-2005	RAN1#42bis	R1-051029			Basic transmission schemes	0.2.0	0.2.1
10-2005	RAN1#42bis	R1-051252			Raised to v0.3.0 following presentation of v0.2.1 at RAN1#42bis	0.2.1	0.3.0
11-2005	RAN1#43	R1-051305			Duplexing, basic transmission schemes, multiplexing, enhanced modulation schemes	0.3.0	0.3.1
11-2005	RAN1#43	R1-051569			Raised to v0.4.0 following presentation of v0.3.1 at RAN1#43	0.3.1	0.4.0
11-2005	RAN1#43	R1-051623			Reference signal structure for OFDM, Basic scheme for MC-WCDMA, Initial simulation results, Multiplexing	0.4.0	0.4.1
11-2005	RAN1#43	R1-051264			MIMO	0.4.1	0.4.2
11-2005	RAN#30	RP-050729			Raised to v0.4.0 following presentation of v0.4.2 at RAN1#43	0.4.2	0.5.0
11-2005	RAN#30				Endorsed to v1.0.0	0.5.0	1.0.0
11-2005					Following by the decision in RAN#30 (RP-050909), scope is updated	1.0.0	1.0.1
2-2006					Reference signal structure, multiplexing, Scheduling, HARQ, Link adaptation is updated	1.0.1	1.0.2
2-2006	RAN1#44	R1-060363			Editorial correction	1.0.2	1.0.3
2-2006	RAN1#44	R1-060714			Raised to v1.1.0 following presentation of v1.0.0 at RAN1#42bis	1.0.3	1.1.0
2-2006	RAN1#44	R1-060763			Interference mitigation, Scheduling, HARQ, Link adaptation in UL, MIMO etc.	1.1.0	1.1.1
3-2006	RAN#31	RP-060178			Raised to v1.2.0 following presentation of v1.1.1 at RAN1#44	1.1.1	1.2.0

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