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High Speed Uplink Packet Access (HSUPA) White Paper

Application Note 1MA94

High Speed Uplink Packet Access (HSUPA) is a 3GPP release 6 feature for WCDMA. Objective is to achieve uplink data rates of up to 5.76 Mbps and increase throughput and capacity. This application note introduces HSUPA concepts and explains key features.



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The following abbreviations are used in this application note for R&S test equipment:

- The Vector Signal Generator R&S® SMU200A is referred to as the SMU200A.
- The Vector Signal Generator R&S® SMATE200A is referred to as the SMATE200A.
- The Vector Signal Generator R&S® SMJ100A is referred to as the SMJ100A.
- SMU200A, SMATE200A, and SMJ100A in general is referred to as the SMx.
- The Spectrum Analyzer R&S® FSP and FSU are referred to as FSP and FSU.
- The Signal Analyzer R&S® FSQ is referred to as FSQ.
- FSP, FSU and FSQ in general is referred to as the FSx.
- The Protocol Tester R&S® CRTU-W is referred to as CRTU-W.
- The Protocol Tester R&S® CRTU-M is referred to as CRTU-M.

1 Introduction

The number of UMTS subscribers worldwide is rapidly increasing. They use the data card in their notebook to access data on the road, or use their mobile phone to try out innovative applications, including watching mobile TV or downloading video sequences. UMTS already offers data services of the highest quality, typically reaching data rates of 384 kbps. All of these applications result in an ever-increasing amount of data traffic in the mobile radio network- over and beyond the conventional, line-switched call load.

For these reasons, High Speed Downlink Packet Access (HSDPA) and High Speed Uplink Packet Access (HSUPA) have been developed to enhance UMTS technology for data transmission.

HSDPA has been included in the release 5 of 3GPP standards and is currently being deployed in 3G networks worldwide. HSDPA makes downlink data rates of up to (theoretically) 14 Mbps possible and significantly increases the capacity of the mobile network.

HSUPA is the next evolution step for UMTS networks. The technology which is also known as FDD Enhanced Uplink (EUL) has been introduced in the release 6 of 3GPP standards. Objective of HSUPA is to enhance uplink packet data transmission by achieving data rates of up to 5.76 Mbps. Furthermore, HSUPA will increase uplink capacity and reduce latency. A combination of HSDPA and HSUPA is especially beneficial, since it will allow optimized packet data transfer in downlink and uplink.

Services that benefit from HSUPA are multimedia applications requiring excellent uplink performance, e.g. gaming, video streaming, file upload.

This application note gives an introduction to HSUPA technology.

Chapter 2 outlines HSUPA key features and the impact on the radio access network architecture.

Chapter 3 describes the structure of new physical and transport channels that are used in HSUPA.

Chapter 4 details the HSUPA scheduling mechanism, and

Chapter 5 explains the Hybrid ARQ (Automatic Repeat Request) retransmission protocol used in HSUPA.

Chapter 6 gives an overview of HSUPA terminal categories.

Chapters 7-9 provide additional information including literature references.

This application note assumes basic knowledge of HSDPA concepts [1].

2 Key Features of HSUPA

Uplink Scheduling

The **uplink scheduling** mechanism is of central importance for HSUPA. The uplink scheduler is located in the Node B close to the air interface (cmp. the HSDPA downlink scheduler, also being located in the Node B).

Task of the uplink scheduler is to control the uplink resources the UEs in the cell are using. The scheduler therefore grants maximum allowed

transmit power ratios to each UE. This effectively limits the transport block size the UE can select and thus the uplink data rate.

The scheduling mechanism is based on **absolute and relative grants**. The absolute grants are used to initialize the scheduling process and provide absolute transmit power ratios to the UE, whereas the relative grants are used for incremental up- or downgrades of the allowed transmit power.

Note that one UE has to evaluate scheduling commands possibly from different radio links. This is due to the fact that uplink macro diversity is used in HSUPA.

Hybrid Automatic Repeat Request (HARQ)

The HARQ protocol is a retransmission protocol improving robustness against link adaptation errors. The Node B can request retransmissions of erroneously received data packets and will send for each packet either an acknowledgement (ACK) or a negative acknowledgement (NACK) to the UE. Furthermore, the Node B can do soft combining, i.e. combine the retransmissions with the original transmissions in the receiver.

Due to uplink macro diversity, one UE has to evaluate ACK/NACK information for the same packet possibly from different radio links.

Reduction of Transmission Time Interval

To accelerate packet scheduling and reduce latency, HSUPA allows for a reduced transmission time interval (TTI) of 2 ms corresponding to 3 timeslots. A WCDMA radio frame of 10 ms therefore consists of 5 sub-frames.

Unlike HSDPA, however, the support of this 2 ms TTI in the UE is not mandatory. Instead, it is a UE capability. It is configured at call setup whether 2 ms TTI or 10 ms TTI is to be used for HSUPA transmission.

Impact on Radio Access Network Architecture

Both the uplink scheduling and the HARQ protocol are located in the Node B, in order to move processing closer to air interface and be able to react faster on the radio link situation. This is illustrated in figure 1.

Macro diversity is exploited for HSUPA, i.e. the uplink data packets can be received by more than 1 cell. There is one **serving cell** controlling the serving radio link assigned to the UE. The serving cell is having full control of the scheduling process and is providing the absolute grant to the UE. The **serving radio link set** is a set of cells contains at least the serving cell and possibly additional radio links from the same Node B. The UE can receive and combine one relative grant from the serving radio link set.

There can also be additional **non-serving radio links** at other Node Bs. The UE can have zero, one or several non-serving radio links and receive one relative grant from each of them.

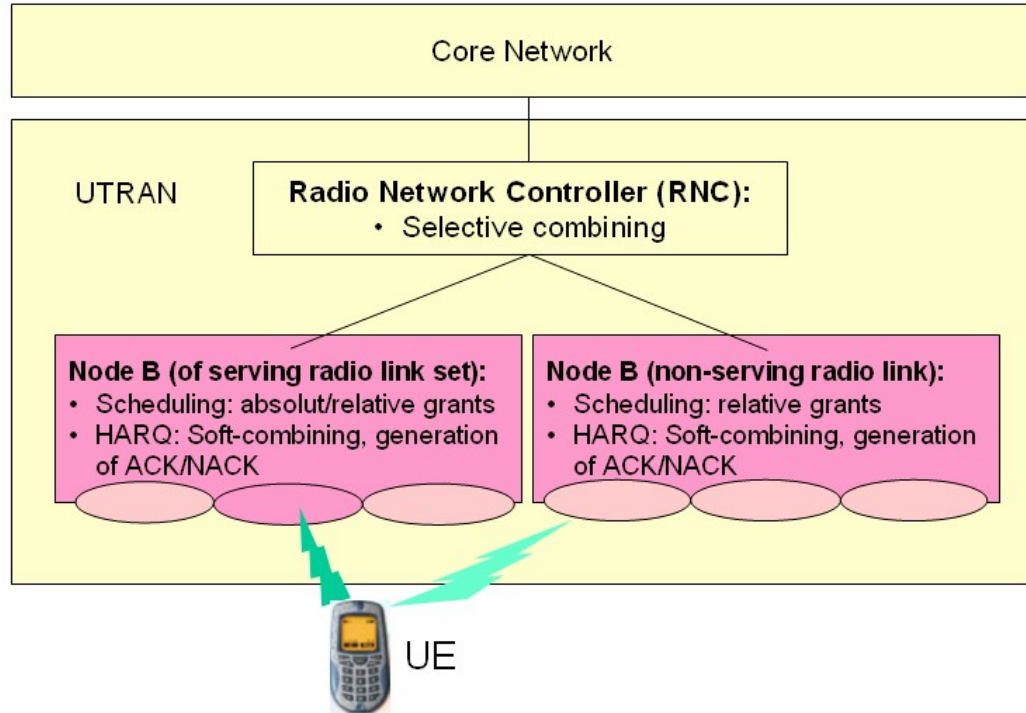


Figure 1 Impact of HSUPA on Radio Access Network Architecture

Different Node Bs will deliver correctly received data packets to the Radio Network Controller (RNC). Therefore some selective combining functionality is needed in the RNC to sort out duplicates.

The HSUPA related functionalities in Node B and RNC are also reflected in the protocol architecture as shown in figure 2 (co-incident Serving and Controlling RNC). New protocol entities are highlighted in blue.

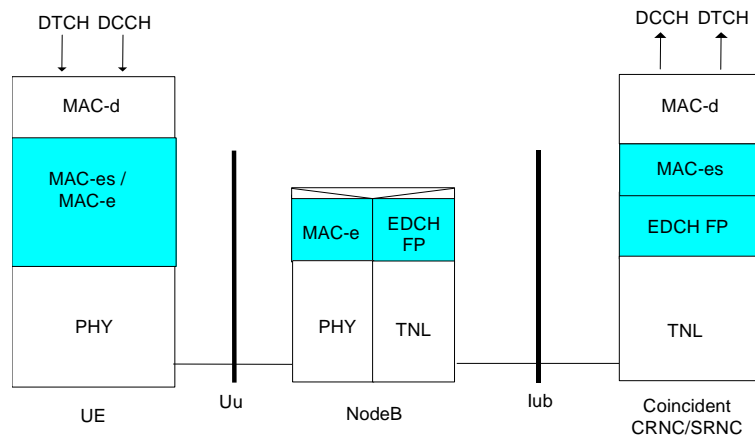


Figure 2 Protocol Architecture for HSUPA [Coincident CRNC and SRNC]

Node B contains a new Medium Access Control entity called **MAC-e**, and the RNC contains a new Medium Access Control entity called **MAC-es**. Both MAC-e and MAC-es entities terminate within the Medium Access Control layer of the UE.

3 New Physical and Transport Channels

Within the HSUPA framework, the Enhanced Dedicated Channel (**E-DCH**) is introduced as a new transport channel for carrying user data on the uplink. On physical layer level, this translates into 2 new uplink channels:

- E-DCH Dedicated Physical Data Channel (**E-DPDCH**), and
- E-DCH Dedicated Physical Control Channel (**E-DPCCH**).

The E-DPCCH carries control information associated to the E-DPDCH.

In the downlink, 3 new channels are introduced for control purposes:

- **E-AGCH**: E-DCH Absolute Grant Channel carrying absolute grants
- **E-RGCH**: E-DCH Relative Grant Channel carrying relative grants
- **E-HICH**: E-DCH Hybrid ARQ Indicator Channel carrying ACK/NACK

E-AGCH is only transmitted from the serving cell. E-RGCH and E-HICH are transmitted from radio links that are part of the serving radio link set and from non-serving radio links.

Figure 3 shows an overview of the HSUPA related channels.

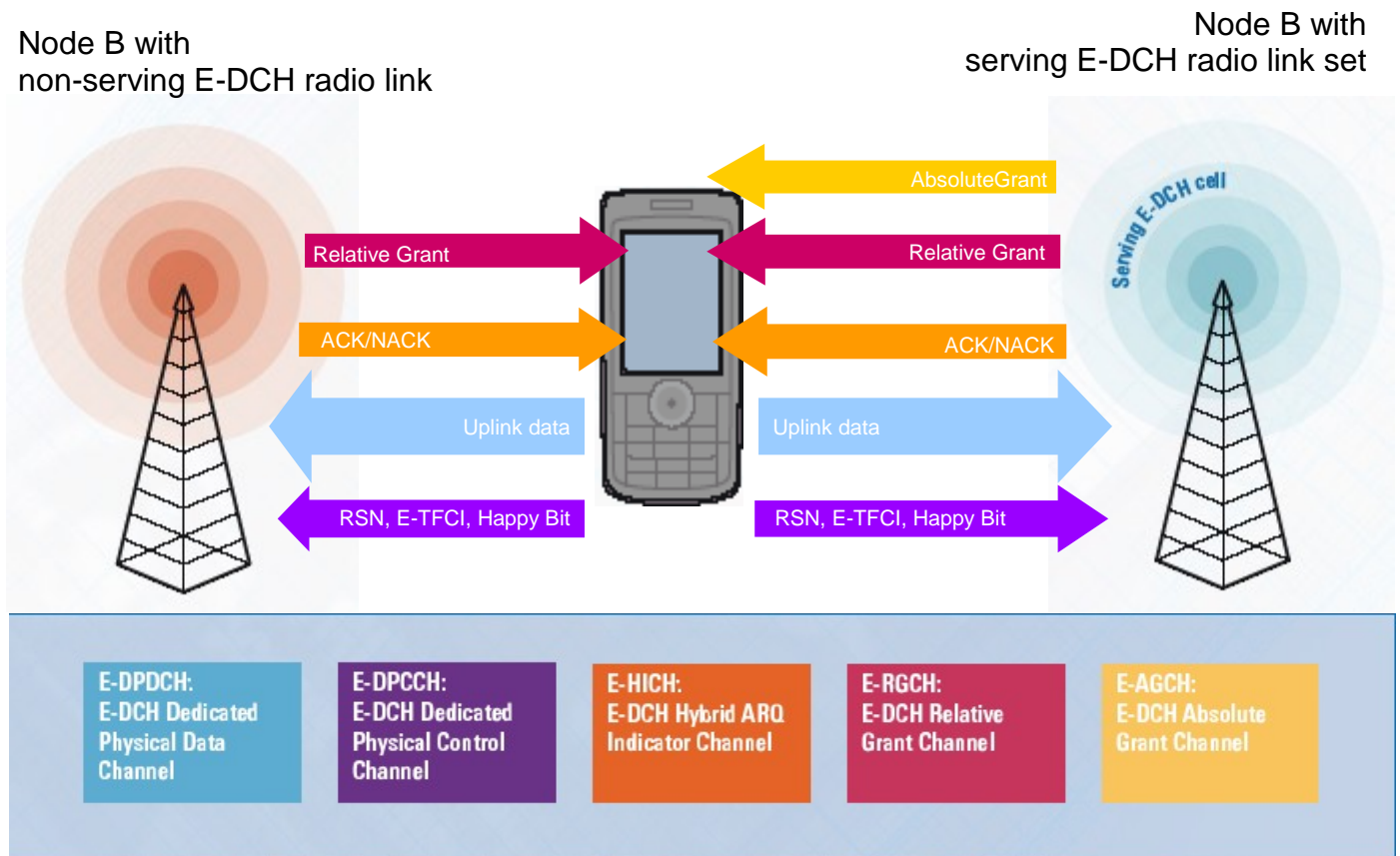


Figure 3 Overview of HSUPA Channels

Note that HSUPA channels are added on top of uplink / downlink dedicated channels. Each UE therefore additionally carries an uplink and downlink dedicated physical channel (DPCH). In the downlink, a fractional dedicated

channel (F-DPCH) can be used alternatively. The **F-DPCH** has been introduced in 3GPP release 6 in order to optimize the downlink channelization code usage. With this concept, several UEs can share one downlink channelization code of spreading factor (SF) 256. For this purpose, the F-DPCH uses a new slot format only containing the Transmit Power Control (TPC) bits. Unlike the regular downlink DPCH slot formats, no pilot or data fields are present. By assigning a UE specific timing offset, it is possible to multiplex up to 10 UEs onto one channelization code for F-DPCH.

Figure 4 illustrates the possibility to configure a downlink DPCH as F-DPCH.

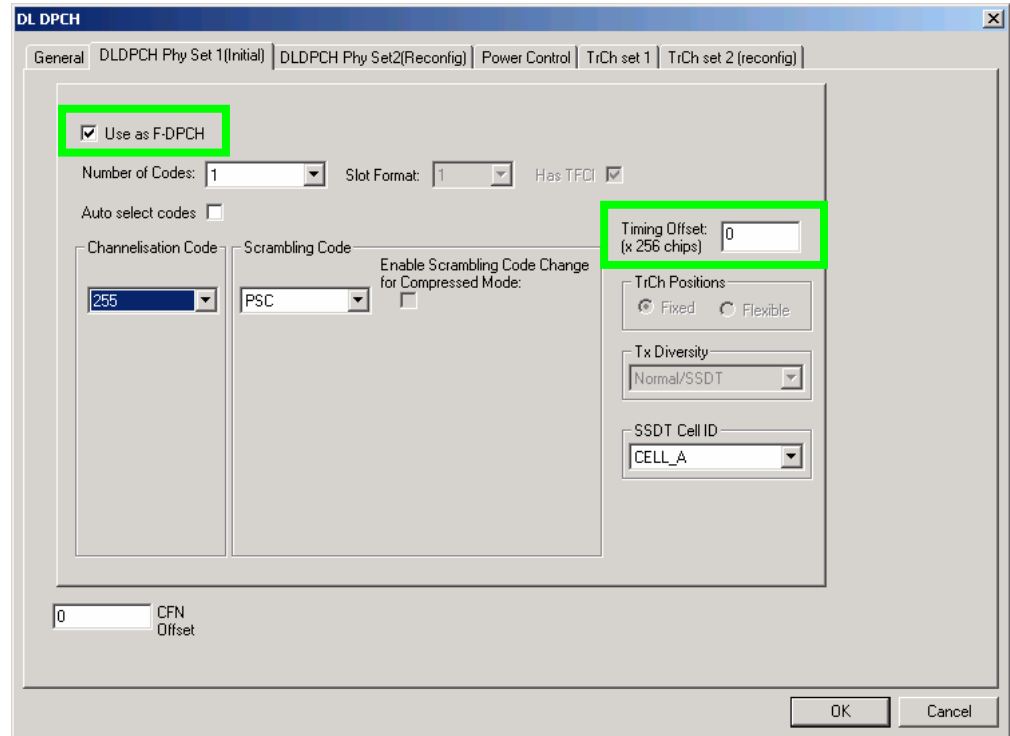


Figure 4 Configuration of F-DPCH in Layer 1 Test Software for CRTU-W/M

All HSUPA related channels are described in more detail in the following:

E-DCH Dedicated Physical Data Channel: E-DPDCH

Figure 5 shows the structure of the E-DPDCH. An E-DCH transport block with user data is mapped onto one sub-frame of 2 ms in case a TTI of 2 ms has been configured, or onto one radio frame of 10 ms in case a TTI of 10 ms has been configured.

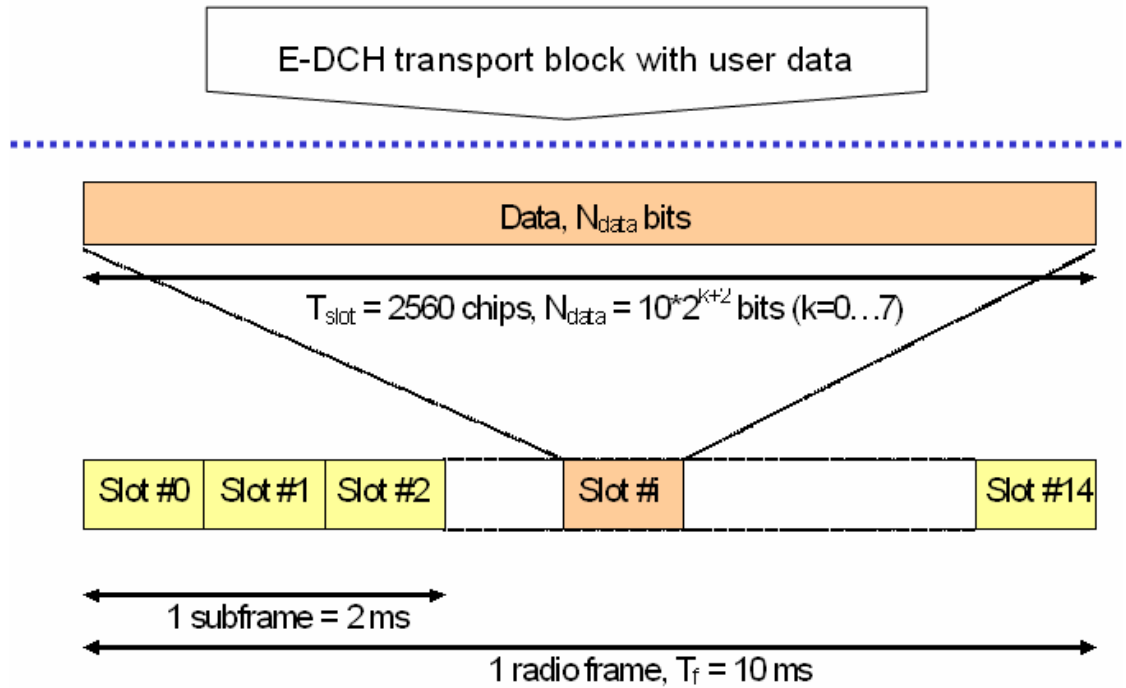


Figure 5 Structure of E-DPDCH [2]

BPSK is used as modulation scheme on E-DPDCH.

The amount of data bits that can be carried within one timeslot depends on the selected slot format. The slot format determines the spreading factor (SF) and therefore the amount of bits per slot, see table 1.

Spreading factors 2 up to 256 are available for use on E-DPDCH. Note that a minimum spreading factor of 2 is not supported by all UE categories.

Multicode transmission is possible: 2 channelization codes of SF 2, 2 channelization codes of SF 4, or a combination of 2 channelization codes of SF2 and 2 channelization codes of SF4 can be selected.

Table 1 E-DPDCH Slot Formats [2]

Slot Format #i	Channel Bit Rate (kbps)	SF	Bits/ Frame	Bits/ Subframe	Bits/Slot N_{data}
0	15	256	150	30	10
1	30	128	300	60	20
2	60	64	600	120	40
3	120	32	1200	240	80
4	240	16	2400	480	160
5	480	8	4800	960	320
6	960	4	9600	1920	640
7	1920	2	19200	3840	1280

The maximum possible data rate of 5.76 Mbps is achieved by allocating $2 \cdot SF2$ and $2 \cdot SF4$.

As channel coding on E-DPDCH, turbo coding with code rate $1/3$ is used.

The E-DPDCH is time aligned with the uplink Dedicated Physical Control Channel (DPCCH).

E-DCH Dedicated Physical Control Channel: E-DPCCH

Figure 6 shows the structure of the E-DPCCH which is associated to the E-DPDCH in uplink. The E-DPCCH is a physical channel carrying control information for the E-DPDCH:

- The retransmission sequence number (RSN) used in the HARQ protocol (2 bits)
- An E-DCH Transport Format Combination Indicator (E-TFCI) identifying the transport block size on E-DCH (7 bits)
- A "Happy Bit" as scheduling feedback from the UE (1 bit), see chapter 4

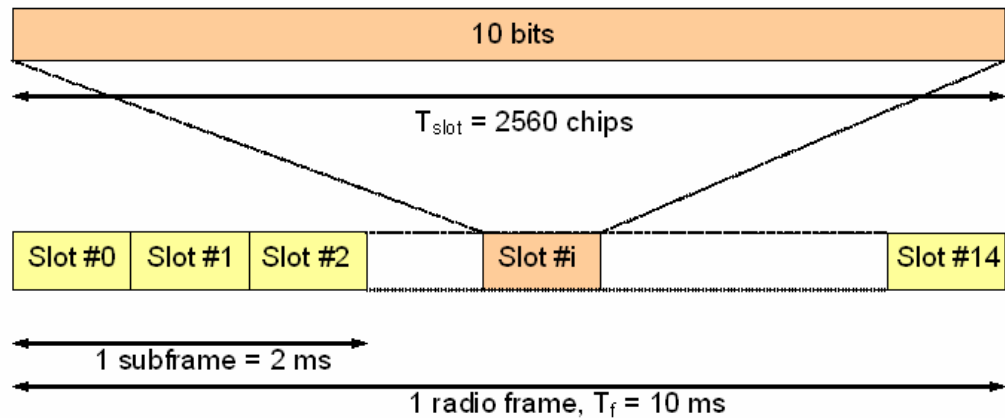


Figure 6 Structure of E-DPCCH [2]

The E-DPCCH is transmitted on channelization code 1 of spreading factor 256. BPSK modulation is used.

The 10 bit information to be carried on E-DPCCH is multiplexed and channel coded with a sub-code of the second order Reed-Muller code, resulting in 30 bits to be transmitted. In case of 2 ms TTI, these 30 bits are transmitted in one sub-frame of 2 ms. In case of 10 ms TTI, these 30 bits are repeated in 5 sub-frames.

The E-DPCCH is time aligned with the uplink DPCCH.

All channels transmitted in uplink (E-DPDCH, E-DPCCH, HS-DPCCH, DPCCH, possibly DPDCH) are IQ multiplexed, see figure 7.

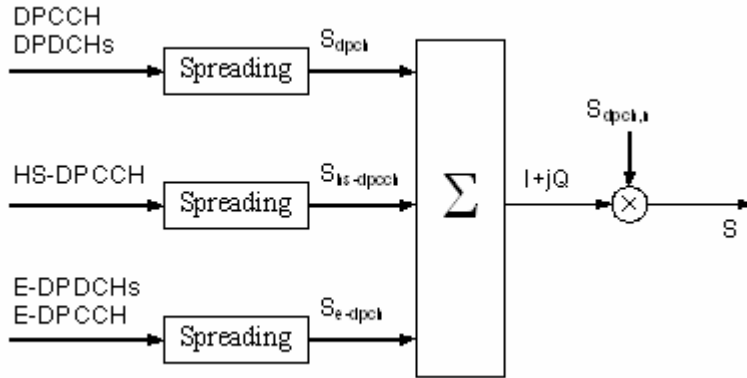


Figure 7 Uplink Spreading Operation for Dedicated Channels (DPCCH/DPDCHs), HSDPA (HS-DPCCH), and HSUPA (E-DPDCHs, E-DPCCH) [3]

The E-DPCCH is always mapped onto the I branch and spread with the first channelization code of SF256. The mapping of the E-DPDCH(s) depends on the maximum number of DPDCHs configured ($N_{max-dpdch}$) and on whether HSDPA is configured or not, see table 2.

Table 2 Mapping of E-DPDCHs onto I/Q domain [3]

$N_{max-dpdch}$	HS-DSCH configured	E-DPDCH _k	iq_{e-dch}
0	No/Yes	E-DPDCH ₁	1
		E-DPDCH _j	j
		E-DPDCH ₂	1
		E-DPDCH _k	j
1	No	E-DPDCH ₁	j
		E-DPDCH ₂	1
1	Yes	E-DPDCH ₁	1
		E-DPDCH ₂	j

Note that the possible uplink channel combinations are limited. Table 3 shows the allowed configurations.

Table 3 Uplink Channel Configurations [3]

Configuration #	DPDCH	HS-DPCCH	E-DPDCH	E-DPCCH	Comment
1	6	1	-	-	R99 + HSDPA(R5)
2	1	1	2	1	R99 + HSDPA + HSUPA
3	-	1	4	1	HSDPA + HSUPA

The selection of the channelization codes is also determined by the configuration. Figure 8 shows the resulting code domain display for configuration#3. On the I domain (upper part of the figure), you can see the E-DPCCH, as well as 1 E-DPDCH with SF2, and 1 E-DPDCH with SF4. On the Q domain (lower part of the figure), you can see the DPCCH, the HS-DPCCH, 1 E-DPDCH with SF2, and 1 E-DPDCH with SF4. No DPDCH is configured.

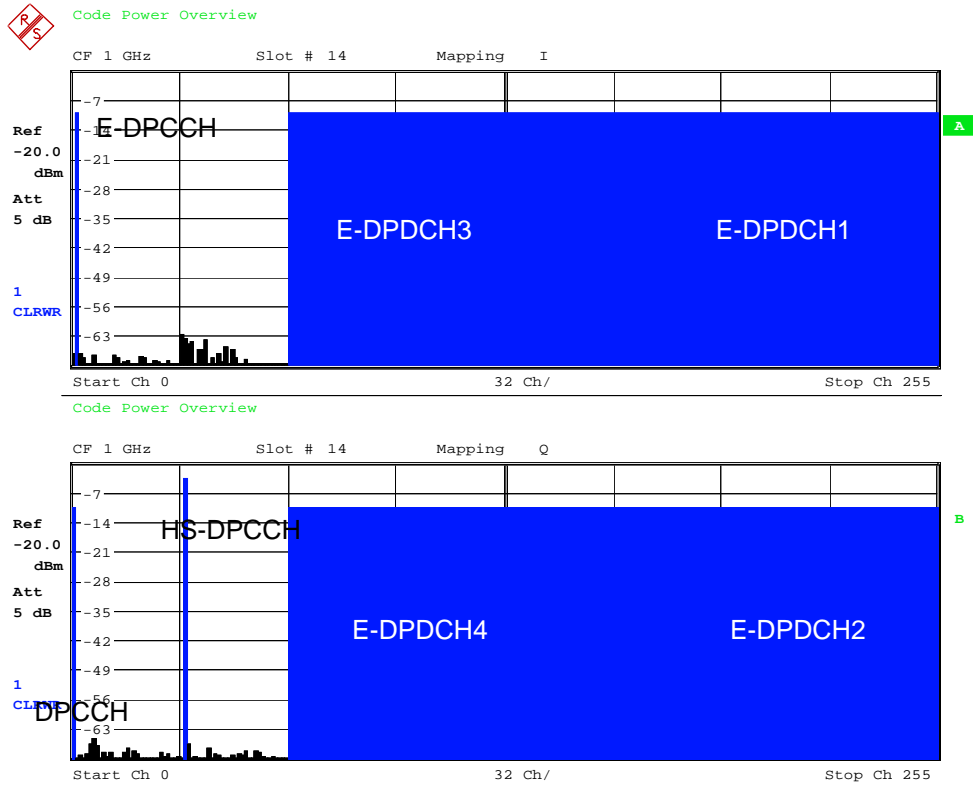


Figure 8 Code domain display of HSUPA uplink signal, measured with FSQ

In figure 8, E-DPDCH1 and E-DPDCH2 use the same channelization code (1st code of SF2), and E-DPDCH3 and E-DPDCH4 use the same channelization code (1st code of SF4). HS-DPCCH uses code 33 of SF256 in this configuration.

Figure 9 illustrates the mapping of the E-DPDCHs for configuration#3.

E-DPDCH Settings				
Data 1280				
State	<input type="checkbox"/> On		Channel Power	0.00 dB
<<< Hide Details				
Overall Symbol Rate	2x960 + 2x1920 ksps			
E-DCH TTI	2 ms	Use	<input type="checkbox"/> DTX Pattern (bin)	1...
	1	2	3	4
Channel Type	E-DPDCH	E-DPDCH	E-DPDCH	E-DPDCH
Symbol Rate / State	1920	1920	960	960
ChannelizationCode	I / 1	Q / 1	I / 1	Q / 1
E-DPDCH Data Source	PN 9	PN 9	PN 9	PN 9
E-DPDCH Pattern	0	0	0	0
E-DPDCH Data List	None	None	None	None

Figure 9 Configuration of 4 E-DPDCHs with SMx Signal Generator

Figure 10 shows another example with 2 E-DPDCHs of SF4.

E-DPDCH Settings

Data
1280

State On Channel Power dB

<<< Hide Details

Overall Symbol Rate E-DCH TTI Use DTX Pattern (bin)

	1	2	3	4
Channel Type	E-DPDCH	E-DPDCH	E-DPDCH	E-DPDCH
Symbol Rate / State	960	960	Off	Off
ChannelizationCode	I / 1	Q / 1		
E-DPDCH Data Source	PN 9	PN 9		
E-DPDCH Pattern	0	0		
E-DPDCH Data List	None	None		

Figure 10 Configuration of 2 E-DPDCHs with SMx Signal Generator

E-DCH Absolute Grant Channel: E-AGCH

The E-AGCH is a downlink physical channel used to transmit absolute grants to a UE or a group of UEs. Please note that it is only transmitted from the serving cell. The E-AGCH structure is outlined in figure 11.

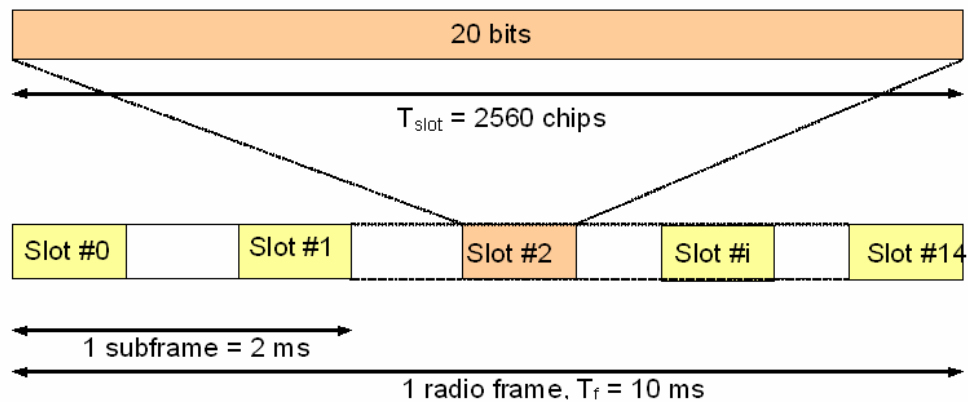


Figure 11 Structure of E-AGCH [2]

The E-AGCH uses a fixed spreading factor of 256 and QPSK modulation.

The absolute grant consists of a 5 bit grant value according to table 4 and 1 bit indicating the scope of the grant. The scope of the absolute grant tells the UE whether the absolute grant is valid for a specific HARQ process or for all HARQ processes.

Table 4 Mapping of 5 bit Absolute Grant Value [4]

Absolute Grant Value	Index		
$(168/15)^2 \times 6$	31		
$(150/15)^2 \times 6$	30		
$(168/15)^2 \times 4$	29	$(75/15)^2$	16
$(150/15)^2 \times 4$	28	$(67/15)^2$	15
$(134/15)^2 \times 4$	27	$(60/15)^2$	14
$(119/15)^2 \times 4$	26	$(53/15)^2$	13
$(150/15)^2 \times 2$	25	$(47/15)^2$	12
$(95/15)^2 \times 4$	24	$(42/15)^2$	11
$(168/15)^2$	23	$(38/15)^2$	10
$(150/15)^2$	22	$(34/15)^2$	9
$(134/15)^2$	21	$(30/15)^2$	8
$(119/15)^2$	20	$(27/15)^2$	7
$(106/15)^2$	19	$(24/15)^2$	6
$(95/15)^2$	18	$(19/15)^2$	5
$(84/15)^2$	17	$(15/15)^2$	4
		$(11/15)^2$	3
		$(7/15)^2$	2
		ZERO_GRANT*	1
		INACTIVE*	0

*Values ZERO_GRANT and INACTIVE are explained in chapter 4.

The absolute grant is channel coded with convolutional coding of code rate 1/3. The resulting 60 bits are transmitted in a 2 ms sub-frame in case of 2 ms TTI, or repeated in all 5 sub-frames in case of 10 ms TTI.

A UE specific CRC attachment is used to address different UEs on E-AGCH. Furthermore, each UE can be configured with a primary E-RNTI (Radio Network Temporary Identifier) and a secondary E-RNTI. The purpose of this is explained in chapter 4.

For both 2 ms and 10 ms TTI, the E-AGCH timing is 5120 chips offset from P-CCPCH frame timing.

E-DCH Relative Grant Channel: E-RGCH, E-DCH Hybrid ARQ Indicator Channel: E-HICH

Although the downlink dedicated physical channels E-RGCH and E-HICH serve two completely different purposes, they share the same structure.

The **E-RGCH** carries relative grants that are used in the scheduling process to incrementally adjust the allowed UE transmit power. A UE can receive and combine one relative grant from all the E-RGCHs transmitted within the serving radio link set. This relative grant from the serving radio link set can take values UP (+1), DOWN (-1) or HOLD (0). In addition, the UE can receive one relative grant from each of the non-serving radio links. These relative grants can take the values DOWN (-1) or HOLD (0). This differentiation has been made to allow only the serving radio link set to

increase the uplink power. Non-serving radio links can only indicate overload situations.

Please note the following differences in relative grant transmission:

- In case a 2 ms TTI has been configured, the relative grant of the serving radio link set is transmitted in one sub-frame of 2 ms.
- In case a 10 ms TTI has been configured, the relative grant of the serving radio link set is transmitted in 12 slots.
- The relative grant of a non-serving radio link is transmitted in 15 slots.

This has been done to optimize processing time requirements for the UE.

The **E-HICH** carries the HARQ acknowledgement indicator, ACK or NACK. The acknowledgement indicator transmitted from the serving radio link set can take the values ACK (+1) or NACK (-1). The acknowledgement indicator transmitted from a non-serving radio link can take the values ACK (+1) or NACK (0).

For both serving radio link set and non-serving radio links, the acknowledgement indicator is transmitted in 3 slots in case of 2 ms TTI, or in 12 slots in case of 10 ms TTI.

Figure 12 shows the structure of E-RGCH and E-HICH.

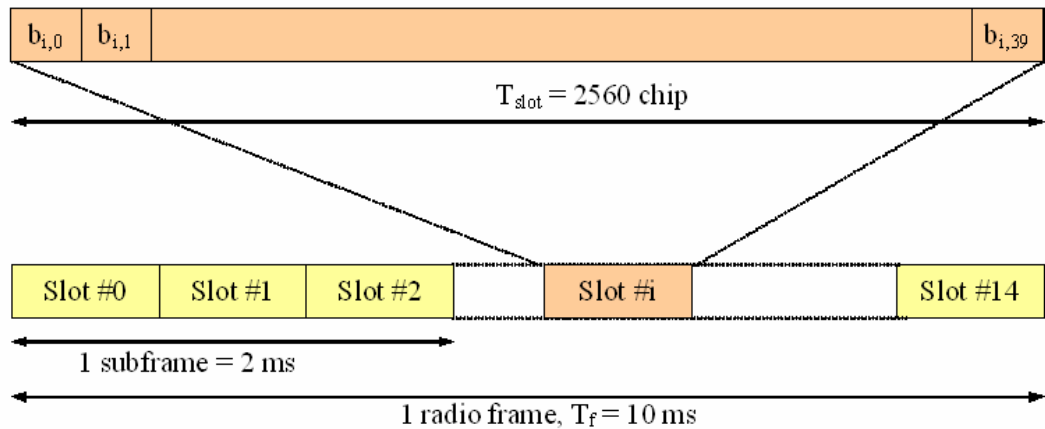


Figure 12 Structure of E-RGCH and E-HICH [2]

E-HICH and E-RGCH use spreading factor 128 and QPSK modulation. E-HICH and E-RGCH of one UE share the same channelization code as assigned by higher layers. They are differentiated by a signature hopping pattern as described in the following.

In each slot i , the sequence $b_{i,0}, b_{i,1}, \dots, b_{i,39}$ is transmitted as shown in figure 12. $b_{i,j}$ results from the use of an orthogonal signature sequence $C_{\text{ss},40,m(i),j}$ such that:

$$b_{i,j} = a C_{\text{ss},40,m(i),j}$$

Where a is the relative grant in case of E-RGCH, or the acknowledgement indicator in case of E-HICH. The value a is set to 0, +1 or -1 depending on what is transmitted (see above in this section).

The signature sequences $C_{\text{ss},40,m(i),j}$ are specified in [2]. Figure 13 shows an extract of the table containing the 40 signature sequences $C_{\text{ss},40,m(i),j}$.

$C_{SS,40,0}$	-1	-1	-1	1	-1	1	-1	-1	1	1	-1	-1	1	1	-1	1	1	-1	-1	-1	-1	1	-1	1	-1	1	1	1	-1	-1	1	1	1	-1	-1	-1	-1		
$C_{SS,40,1}$	-1	1	1	-1	-1	1	1	1	-1	-1	1	-1	1	1	-1	-1	-1	1	1	1	-1	-1	1	-1	1	-1	-1	1	1	-1	1	1	-1	1	1	-1	-1		
$C_{SS,40,2}$	-1	-1	-1	1	-1	1	1	1	-1	-1	-1	1	1	-1	-1	1	1	1	-1	-1	1	1	1	-1	1	-1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1		
$C_{SS,40,3}$	1	-1	-1	-1	-1	-1	1	1	1	-1	-1	1	-1	1	-1	-1	1	1	-1	1	-1	1	1	-1	1	-1	1	-1	1	-1	-1	-1	-1	-1	-1	-1	-1		
$C_{SS,40,4}$	1	1	1	-1	-1	1	-1	1	-1	-1	1	1	1	1	1	1	1	-1	1	1	1	1	-1	-1	1	1	-1	1	-1	1	-1	1	1	-1	1	-1	-1		
$C_{SS,40,5}$	-1	1	-1	-1	1	1	1	-1	1	1	-1	1	1	1	1	-1	-1	1	1	1	1	-1	-1	1	-1	1	-1	1	-1	-1	-1	-1	1	1	1	-1	-1		
$C_{SS,40,6}$	1	1	-1	-1	-1	1	1	-1	1	1	-1	-1	1	-1	-1	1	1	-1	1	1	1	-1	1	-1	1	-1	1	-1	1	-1	1	1	-1	1	-1	1	-1	1	
$C_{SS,40,7}$	-1	1	-1	1	1	1	-1	-1	-1	-1	1	1	1	1	-1	-1	-1	1	-1	-1	1	1	1	-1	1	-1	1	1	1	-1	-1	1	1	1	-1	1	1	-1	
$C_{SS,40,8}$	1	1	-1	1	1	-1	1	1	1	1	-1	-1	-1	1	-1	1	1	1	1	-1	1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	
$C_{SS,40,9}$	-1	1	-1	-1	-1	1	-1	-1	-1	-1	1	1	1	-1	1	-1	-1	-1	1	1	-1	1	1	-1	1	1	-1	1	1	1	1	1	1	1	1	-1	1	1	
$C_{SS,40,10}$	-1	1	1	-1	1	1	-1	1	1	1	-1	1	1	1	-1	1	-1	-1	-1	1	1	-1	1	1	-1	1	-1	1	-1	-1	1	1	-1	-1	-1	-1	1	1	
$C_{SS,40,11}$	-1	1	-1	-1	-1	-1	1	1	1	-1	-1	-1	1	1	-1	1	-1	-1	1	1	1	-1	-1	1	1	-1	-1	1	-1	-1	1	1	-1	1	1	-1	-1	-1	
$C_{SS,40,12}$	-1	-1	-1	-1	1	-1	1	1	-1	-1	-1	1	1	1	-1	1	1	1	1	1	-1	1	1	-1	1	1	1	1	-1	-1	-1	-1	1	1	1	-1	-1	1	1
$C_{SS,40,13}$	1	1	1	1	-1	-1	1	-1	-1	-1	-1	1	1	1	-1	-1	-1	1	1	-1	1	1	-1	1	-1	1	-1	1	-1	1	-1	-1	-1	-1	-1	-1	-1	-1	
$C_{SS,40,14}$	-1	1	1	1	-1	-1	-1	1	1	1	-1	-1	1	1	-1	-1	-1	1	1	-1	1	1	1	1	-1	1	1	1	1	1	1	1	1	1	-1	-1	-1	-1	

Figure 13 E-RGCH and E-HICH signature sequences

Which sequence to use in which timeslot is determined by a signature hopping pattern. E-HICH and E-RGCH of one UE use different hopping patterns which are assigned by higher layers and identified by a sequence index l . The signature hopping patterns are specified in [2]. Table 5 shows an extract.

Table 5 Signature hopping patterns for E-HICH and E-RGCH [2]

Sequence index l	Row index $m(i)$ for slot i		
	$i \bmod 3 = 0$	$i \bmod 3 = 1$	$i \bmod 3 = 2$
0	0	2	13
1	1	18	18
2	2	8	33
3	3	16	32
4	4	13	10
5	5	3	25
6	6	12	16
...

Compressed Mode

Downlink Transmission Gaps

For both 2 ms and 10 ms TTI, when downlink transmission gaps overlap E-HICH, E-RGCH or E-AGCH slots, the UE shall decode the information in those slots which do not overlap a downlink transmission gap. The UE may discard E-HICH, E-RGCH or E-AGCH slots which overlap a downlink transmission gap.

The handling of compressed mode uplink transmission gaps during E-DCH transmission depends on the transmission time interval configured.

2 ms TTI, Uplink Transmission Gaps

For 2 ms TTI, the UE shall not transmit any E-DCH data during sub-frames that are fully or partly overlapping with uplink transmission gaps. For sub-frames within compressed frames that are not overlapping with uplink transmission gaps, an adaptation of the gain factors for E-DPCCH and E-DPDCH is required (see below).

10 ms TTI, Uplink Transmission Gaps

For 10 ms TTI, the UE is allowed to transmit E-DCH data in frames containing uplink transmission gaps, but the reduced transmission capacity in those frames needs to be considered. In fact, the amount of bits available for E-DCH transmissions is reduced in this frame. The gain factor of E-DPCCH and E-DPDCH is increased according to the amount of slots

remaining (see below). Figure 14 shows an example for the case where both the initial transmission and the retransmission occur in a compressed frame, and the transmission gap is smaller in the frame of the retransmission.

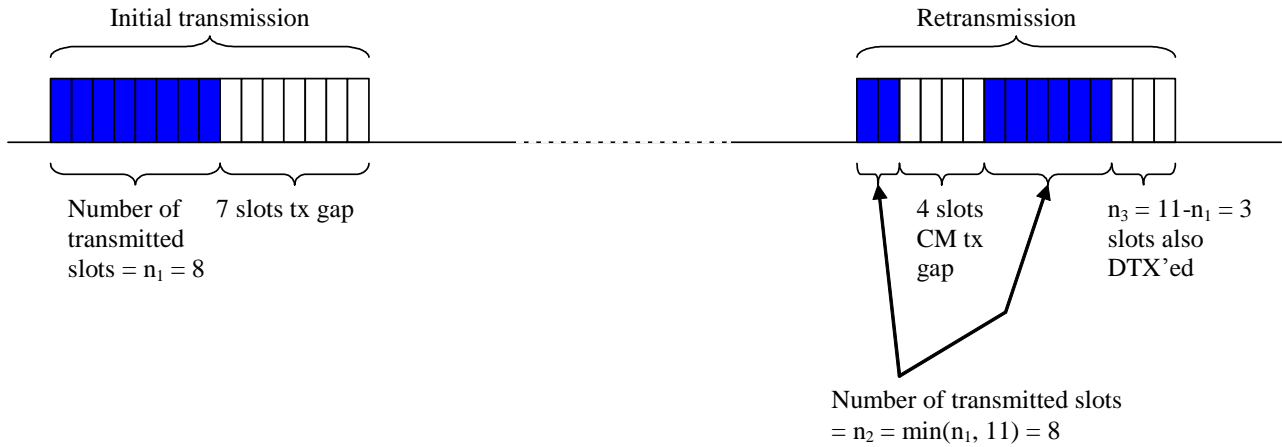


Figure 14 Example for Handling of Compressed Mode, 10 ms TTI

In this case, the 7-slot transmission gap during the initial transmission is larger than the 4-slot transmission gap during the retransmission. To compensate this, the delta of 3 slots is DTX'ed at the end of the frame carrying the retransmission.

Gain Factors for E-DPCCH and E-DPDCH

The power of the E-DPCCH and the E-DPDCH(s) is set in relation to the DPCCH. For this purpose, gain factors are used for scaling the uplink channels relative to each other.

The gain factors are applied individually for E-DPCCH and each E-DPDCH, see figure 15. They are called β_{ec} for E-DPCCH and $\beta_{ed,k}$ for the E-DPDCH(s).

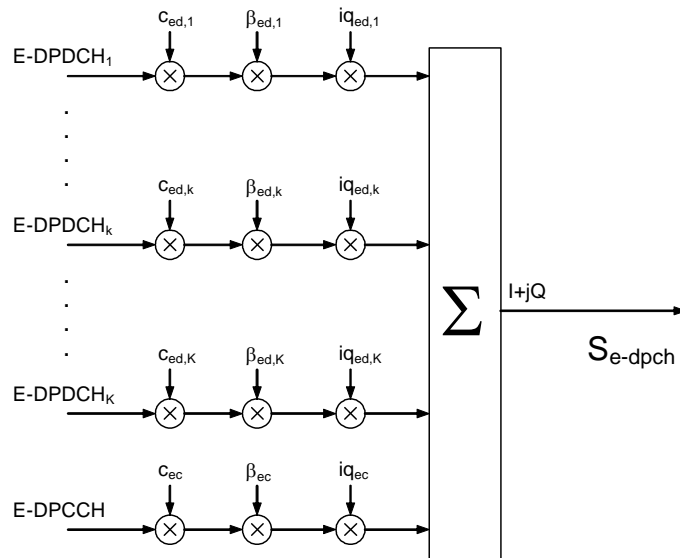


Figure 15 Uplink Spreading and Gain Factor Usage for HSUPA [3]

The UE derives these gain factors from higher layer signaling as follows.

Gain Factor for E-DPCCH

E-DPCCH is scaled with a gain factor β_{ec} , which is given by:

$$\beta_{ec} = \beta_c \cdot A_{ec}$$

where β_c is the gain factor of the DPCCH. β_c is either signaled by higher layers to the UE, or computed according to [5]. The ratio A_{ec} is derived from the parameter $\Delta E-DPCCH$ signaled by higher layers, e.g. at call setup. Table 6 shows the meaning of the signaled values for $\Delta E-DPCCH$. The UE will scale the E-DPCCH in relation to the DPCCH according to the quantized amplitude ratio.

Table 6 Quantization for $\Delta E-DPCCH$ [3]

Signalled values for $\Delta_{E-DPCCH}$	Quantized amplitude ratios $A_{ec} = \beta_{ec}/\beta_c$
8	30/15
7	24/15
6	19/15
5	15/15
4	12/15
3	9/15
2	8/15
1	6/15
0	5/15

During compressed frames, the E-DPCCH gain factor β_{ec} needs to be scaled. This is done in order to avoid that the E-DPCCH power is increased by the offset that is applied to the DPCCH during compressed frames¹.

Therefore, if a 2 ms TTI overlaps with a compressed frame, β_{ec} is given by:

$$\beta_{ec} = \beta_{c,C,j} \cdot A_{ec} \cdot \sqrt{\frac{N_{pilot,C}}{N_{pilot,N}}}$$

$\beta_{c,C,j}$: Beta factor for DPCCH in compressed frames for jth Transport Format Combination (TFC); $\beta_{c,C,j}=1$ when no DPCCH is configured

$N_{pilot,C}$: number of pilot bits per slot on DPCCH in compressed frames

$N_{pilot,N}$: number of pilot bits per slot in non-compressed frames

¹ The uplink DPCCH slot formats that have TFCI bits contain fewer pilot bits than the formats for normal (non-compressed) mode. The reason for this is that the number of TFCI bits shall always be the same during a frame to ensure robust transport format detection. Therefore, in order to keep the same channel quality the energy of the pilot must be kept equal, and the power of the DPCCH shall therefore be increased by the factor $N_{pilot,N}/N_{pilot,C}$

If a 10 ms TTI overlaps with a compressed frame, the E-DPCCH gain factor β_{ec} is additionally scaled (increased) to take into account that less slots are available for transmission during this frame. In order to get a good transmission quality, the transmitted energy per information bit shall be the same independent of whether compressed mode is used in a frame or not. Therefore, β_{ec} is additionally scaled with the factor $15/N_{\text{slots},C}$:

$$\beta_{ec} = \beta_{c,C,j} \cdot A_{ec} \cdot \sqrt{\frac{15 \cdot N_{\text{pilot},C}}{N_{\text{slots},C} \cdot N_{\text{pilot},N}}}$$

$N_{\text{slots},C}$ is the number of non-DTX slots in this compressed frame.

Gain Factor for E-DPDCH

There can be one or more E-DPDCH(s), and each of them is scaled with an own gain factor, see figure 15. The gain factors may vary on radio frame basis or sub-frame basis depending on whether the E-DCH TTI is 10 ms or 2 ms, respectively.

The gain factor $\beta_{ed,k}$ for the kth E-DPCCH is determined by the transport format combination on E-DCH (**E-TFC**) carried in this TTI, and depending on the **HARQ profile** for the data carried in this TTI.

Background:

The E-TFC describes the size of the transport block carried in a TTI. This parameter therefore influences the required transmission power.

For each data flow (MAC-d flow), higher layers can configure an individual HARQ profile. The HARQ profile includes the power offset and maximum number of HARQ retransmissions to use for this MAC-d flow. This can be used to fine-tune operating points for different data flows.

The UE determines the gain factor $\beta_{ed,k}$ based on parameters signaled by higher layers (e.g. at call setup).

First, a “reference E-TFC” needs to be determined in the UE for the E-TFC carried in the regarded TTI. A list of reference E-TFCs containing up to 8 reference E-TFCs is signaled by higher layers. The reference E-TFC is selected as close as possible to the regarded E-TFC [5].

Then, a reference gain factor $\beta_{ed,ref}$ is determined for the selected reference E-TFC:

$$\beta_{ed,ref} = \beta_c \cdot A_{ed}$$

where β_c is the gain factor of the DPCCH. The ratio A_{ed} is derived from the parameter $\Delta E\text{-DPDCH}$ signaled by higher layers for the selected reference E-TFC. Table 7 shows the meaning of the signaled values for $\Delta E\text{-DPDCH}$.

Background:

The reference E-TFC concept is used in order to avoid the signaling overhead which would result from signaling a $\Delta E\text{-DPDCH}$ value for all possible E-TFC values.

Table 7 Quantization for ΔE -DPCCH [3]

Signalled values for ΔE -DPCCH	Quantized amplitude ratios $A_{ed} = \beta_{sd}/\beta_c$
29	168/15
28	150/15
27	134/15
26	119/15
25	106/15
24	95/15
23	84/15
22	75/15
21	67/15
20	60/15
19	53/15
18	47/15
17	42/15
16	38/15
15	34/15
14	30/15
13	27/15
12	24/15
11	21/15
10	19/15
9	17/15
8	15/15
7	13/15
6	12/15
5	11/15
4	9/15
3	8/15
2	7/15
1	6/15
0	5/15

However, this reference gain factor cannot directly be used for scaling the E-DPDCHs, since the reference E-TFC does not reflect the actual E-TFC in terms of number of data bits contained and number of E-DPDCHs required for transmission. Furthermore, the HARQ profile needs to be considered.

Therefore, for the E-TFC to be transmitted in the TTI under consideration (the j th E-TFC), a temporary variable $\beta_{ed,j,harq}$ is computed as:

$$\beta_{ed,j,harq} = \beta_{ed,ref} \sqrt{\frac{L_{e,ref}}{L_{e,j}}} \sqrt{\frac{K_{e,j}}{K_{e,ref}}} \cdot 10^{\left(\frac{\Delta_{harq}}{20}\right)}$$

where

$L_{e,ref}$ is the number of E-DPDCHs used for the reference E-TFC

$L_{e,j}$ is the number of E-DPDCHs used for the j :th E-TFC

$K_{e,ref}$ is the number of data bits of the reference E-TFC

$K_{e,j}$ is the number of data bits of the j :th E-TFC.

Δ_{harq} is the HARQ offset for the specific data flow to be transmitted (so-called "MAC-d flow") as signaled by higher layers (see table 8).

Table 8 HARQ Offset Δ_{harq} [4]

Signalling values for Δ_{harq}	Power offset values Δ_{harq} [dB]
6	6
5	5
4	4
3	3
2	2
1	1
0	0

NOTE: $L_{e,ref}$ and $L_{e,j}$ represent “equivalent” number of physical channels. Normally they are equal to number of used E-DPDCHs except for two cases:

1. 2 x SF2 case: $L_{e,ref}$ and $L_{e,j}$ should be 4 instead of 2.
2. 2 x SF2 + 2 x SF4 case: $L_{e,ref}$ and $L_{e,j}$ should be 6 instead of 4.

Therefore, the calculated $\beta_{ed,j,harq}$ must be scaled by a factor of $\sqrt{2}$ for SF=2 codes. The unquantized gain factor $\beta_{ed,k,j,uq}$ is set to $\sqrt{2} \times \beta_{ed,j,harq}$ for E-DPDCHs using spreading factor 2 and equal to $\beta_{ed,j,harq}$ otherwise. The ratio $\beta_{ed,k,j,uq} / \beta_c$ is now quantized according to table 9 to obtain the ratio $\beta_{ed,k} / \beta_c$.

Table 9 Quantization for $\beta_{ed,k} / \beta_c$ [3]

Quantized amplitude ratios $\beta_{ed,k} / \beta_c$
168/15
150/15
134/15
119/15
106/15
95/15
84/15
75/15
67/15
60/15
53/15
47/15
42/15
38/15
34/15
30/15
27/15
24/15
21/15
19/15
17/15
15/15
13/15
12/15
11/15
9/15
8/15
7/15
6/15
5/15

During compressed frames, the E-DPDCH gain factor $\beta_{ed,k}$ needs to be scaled as follows. The factors applied for the scaling the E-DPDCH have been introduced already in the E-DPCCH section above. Their explanation is not repeated here, but they are highlighted with the same colors as above.

For **2 ms TTI**, the gain factor used for the j th E-TFC in a compressed frame is given by:

$$\beta_{ed,C,j} = \beta_{c,C,j} \cdot A_{ed} \cdot \sqrt{\frac{L_{e,ref}}{L_{e,j}}} \cdot \sqrt{\frac{K_{e,j}}{K_{e,ref}}} \cdot 10^{\left(\frac{\Delta_{harq}}{20}\right)} \cdot \sqrt{\frac{N_{pilot,C}}{N_{pilot,N}}}$$

where

$\beta_{c,C,j}$: DPCCH beta factor in compressed frames for j th TFC ($\beta_{c,C,j}=1$ when no DPDCH is configured)

$N_{pilot,C}$: number of pilot bits per slot on DPCCH in compressed frames

$N_{pilot,N}$: number of pilot bits per slot in non-compressed frames

$N_{slots,C}$: number of DTX slots in this compressed frame

For **10 ms TTI**, the gain factor used for the j th E-TFC in a compressed frame is given by:

$$\beta_{ed,C,j} = \beta_{c,C,j} \cdot A_{ed} \cdot \sqrt{\frac{L_{e,ref}}{L_{e,j}}} \cdot \sqrt{\frac{K_{e,j}}{K_{e,ref}}} \cdot 10^{\left(\frac{\Delta_{harq}}{20}\right)} \cdot \sqrt{\frac{15 \cdot N_{pilot,C}}{N_{slots,I} \cdot N_{pilot,N}}}$$

where

$\beta_{c,C,j}$: beta factor in compressed frames for j th TFC (=1 when no DPDCH is configured)

$N_{pilot,C}$: number of pilot bits per slot on DPCCH in compressed frames

$N_{pilot,N}$: number of pilot bits per slot in non-compressed frames

$N_{slots,I}$: number of non-DTX slots in the first frame used for transmitting the data

Note that in the 10 ms case, retransmissions on E-DPDCH also require scaling when the corresponding initial transmission overlapped a compressed frame (but the frame with the retransmission does not). When the E-DCH TTI is 10 ms and the current frame is not compressed, but is a retransmission for which the corresponding first transmission was compressed, $\beta_{ed,R,j}$ represents the gain factor that shall be applied to the j^{th} E-TFC:

$$\beta_{ed,R,j} = \beta_{ed,j} \cdot \sqrt{\frac{15}{N_{slots,I}}}$$

where $\beta_{ed,j}$ is the gain factor used for the j^{th} E-TFC in non compressed frames.

4 HSUPA Scheduling Mechanism

Serving Grant Update

As a basic principle of the uplink scheduling mechanism, the UE maintains a **servicing grant** which represents the maximum E-DPDCH to DPCCH power ratio the UE may use in the next transmission. This servicing grant is updated at every TTI boundary.

The servicing grant is used as basis for selecting the appropriate E-TFC, because the available uplink power determines the possible data rate. Absolute and relative grants are sent from the network to the UE to control

the serving grant. The absolute and relative grants received are applied at a specific TTI which is implicitly associated (see below in this chapter).

The **absolute grant** allows the Node B scheduler to directly adjust the granted rate of UEs under its control. The E-AGCH is a shared channel that uses an E-RNTI-specific Cyclic Redundancy Check (CRC) in order to address messages to specific users or groups of users. The absolute grant is used to initialize the serving grant.

Furthermore, the absolute grant can be used to control all HARQ processes or one specific HARQ process (the latter is only possible in case of 2 ms TTI). This is indicated by the scope bit transmitted together with the grant value on E-AGCH. It is also possible to de-activate specific HARQ processes in case of 2 ms TTI.

The **relative grants** are used to incrementally adjust the UE's serving grants. For the non-serving radio links, the relative grants are a means to avoid overload situations by transmitting a "DOWN" on E-RGCH. For the serving E-DCH radio link set, also transmission of an "UP" is possible. All radio links which are part of the Serving E-DCH radio link set transmit the same relative grant value.

When a UE receives a relative grant to be applied for a specific TTI, the serving grant is updated based on the scheduling grant table, see table 10. The UE will first determine an index in the SG-table close to the E-DPDCH/DPCCH power ratio used for the previous TTI on this HARQ process (also called SG_{LUPR}; LUPR = Last Used Power Ratio).

For interpretation of the "UP", the network can configure the terminal with so-called "**3-index-step threshold**" and "**2-index-step threshold**" values. Depending on whether the current SG-table index is smaller than the "3-index-step threshold" value, in-between the "3-index-step threshold" value and the "2-index-step threshold" value or bigger than the "2-index-step threshold" value, the UE will set the new serving grant to the value in the SG-table with SG-index + 3, SG-index + 2, or SG-index +1, respectively. This concept ensures that different step sizes (app. in the range from 1 to 3 dB) can be achieved depending on the last used power ratio and network configuration of the values for 3-index-step and 2-index-step threshold.

This is illustrated in an example next to table 10.

In case UE has received a "DOWN", the new serving grant is derived by decrementing the serving grant table index by 1. This is independent from whether the DOWN command was received from a non-serving radio link or from the serving radio link set.

With this design of the serving grant table, it is possible to direct the UE with E-RGCH commands to lower power ratio levels than can be obtained by only using E-AGCH commands. The absolute grants that can be signaled on E-AGCH are a subset of the SG table.

If the variable Serving_Grant has the value "Zero_Grant" after the Serving Grant Update, then the serving grant shall not be taken into account in the upcoming transmission.

If the UE has received an absolute grant, it will ignore any serving cell E-RGCH commands for one HARQ cycle (40ms in the case of 10 ms TTI, 16ms in the case of 2 ms TTI).

After reception of a non-serving radio link "DOWN" command, the serving grant is saturated for one HARQ cycle. This means that during this time, the maximum E-DPDCH to DPCCH power ratio that the UE is allowed to use shall not be incremented above the latest serving grant.

In case of 10ms TTI and the TTI for the upcoming transmission overlaps with a compressed mode gap, the Serving Grant provided by the Serving Grant Update function shall be scaled back as follows:

$$SG' = SG * \left(\frac{N_C}{15}\right)$$

where SG' represents the modified serving grant considered by the E-TFC selection algorithm and N_C represents the number of non DTX slots in the compressed TTI.

Table 10 Scheduling Grant Table, SG-table [6]

Index	Scheduled Grant
37	$(168/15)^2 * 6$
36	$(150/15)^2 * 6$
35	$(168/15)^2 * 4$
34	$(150/15)^2 * 4$
33	$(134/15)^2 * 4$
32	$(119/15)^2 * 4$
31	$(150/15)^2 * 2$
30	$(95/15)^2 * 4$
29	$(168/15)^2$
28	$(150/15)^2$
27	$(134/15)^2$
26	$(119/15)^2$
25	$(106/15)^2$
24	$(95/15)^2$
23	$(84/15)^2$
22	$(75/15)^2$
21	$(67/15)^2$
20	$(60/15)^2$
19	$(53/15)^2$
18	$(47/15)^2$
17	$(42/15)^2$
16	$(38/15)^2$
15	$(34/15)^2$
14	$(30/15)^2$
13	$(27/15)^2$
12	$(24/15)^2$
11	$(21/15)^2$
10	$(19/15)^2$
9	$(17/15)^2$
8	$(15/15)^2$
7	$(13/15)^2$
6	$(12/15)^2$
5	$(11/15)^2$
4	$(9/15)^2$
3	$(8/15)^2$
2	$(7/15)^2$
1	$(6/15)^2$
0	$(5/15)^2$

Examples for serving grant update when an UP has been received:

1st example: $SG_{LUPR} = 28$

New serving grant value = $SG_{LUPR} + 1$ index step = 29

2-Index-Step Threshold as configured by network

2nd example: $SG_{LUPR} = 17$

New serving grant value = $SG_{LUPR} + 2$ index steps = 19

3-Index-Step Threshold as configured by network

As an additional feature, it is a network option to configure each UE with a **primary E-RNTI** and a **secondary E-RNTI**. This might be helpful in case there are a lot of “always on” UEs which will only occasionally send large amounts of uplink data. The network can assign to this group of UEs a limited secondary grant in order to control this group together. Only if a specific UE needs to send more uplink data, the network would assign an individual primary grant to this UE with the primary E-RNTI. Both primary and secondary E-RNTIs can be initialized and reconfigured by higher layer signaling. By using a UE specific CRC based on the primary or secondary E-RNTI, the absolute grant sent on E-AGCH on serving cell can be unambiguously identified by the UE.

As soon as there is no need for a primary grant any more, it is possible to switch to the secondary grant by indicating “All HARQ Processes” in the scope for the grant value “INACTIVE” for the primary E-RNTI.

Figure 16 illustrates the possibility to configure absolute grants with different scope, either for primary or secondary UE identity.

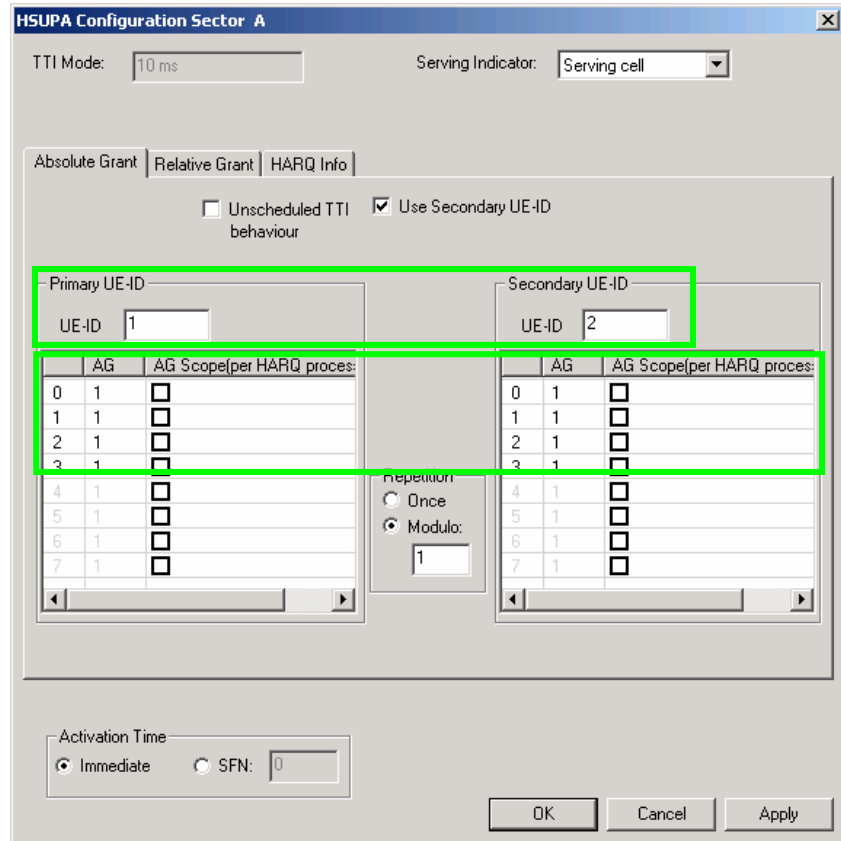


Figure 16 Configuration of E-AGCH Contents with Layer 1 Test Software

As an input to the scheduling algorithm, UE feedback is required. The UE has the possibility to send **scheduling information** as part of the MAC-e Protocol Data Unit (PDU). It provides detailed information about the buffer status in the UE. Therefore, the Node B scheduler can make appropriate scheduling decisions. The scheduling information consists of:

- The identity of the highest priority logical channel with available data (HLID, 4 bits)
- Total E-DCH buffer status (TEBS, 5 bits)
- Buffer occupancy of highest priority logical channel (HLBS, 4 bits)
- UE power headroom as ratio between available UE Tx power and DPCCH power (UPH, 5 bits)

Furthermore, the UE can use the “**happy bit**” on E-DPCCH to indicate that more uplink resources are needed. If the happy bit is set, then it is indicated to the Node B, that more than a specified time (called “Happy_Bit_Delay_Condition”) is required under the given conditions to transmit the data in the UE buffer. Happy_Bit_Delay_Condition can be configured by the network.

Note that the network also has the option to configure **non-scheduled processes** for specific data flows (“MAC-d flows”), i.e. for guaranteed bit

rate services or signaling radio bearers. These data flows can make use of specific HARQ processes as assigned by higher layers and are not subject to scheduling.

Timing of E-AGCH and E-RGCH

Each Absolute Grant or Relative Grant command is applied at a specific TTI. This association is implicit based on the timing of the E-AGCH and E-RGCH as specified in [5]. The timing is tight enough that this relationship is unambiguous.

E-AGCH, 10 ms TTI

The UE uses the control data received in the E-AGCH frame associated to SFN *i* in the E-DPDCH frame associated with SFN *i+1+s*, with *s* equal to:

$$s = \left\lceil \frac{100 - (\tau_{DPCH,n} / 256)}{150} \right\rceil$$

τ_{DPCH} is the offset of the downlink dedicated physical channel as configured by higher layers. τ_{DPCH} can take values from 0...149*256 chips. For low values of τ_{DPCH} , *s*=1. If τ_{DPCH} is further increasing and $\tau_{DPCH} \geq 100 * 256$ chips, *s* gets 0.

Figure 17 shows an example for the timing with *s* = 1. The E-AGCH frame containing the absolute grant and the E-DPDCH frame where the absolute grant is applied are marked in blue.

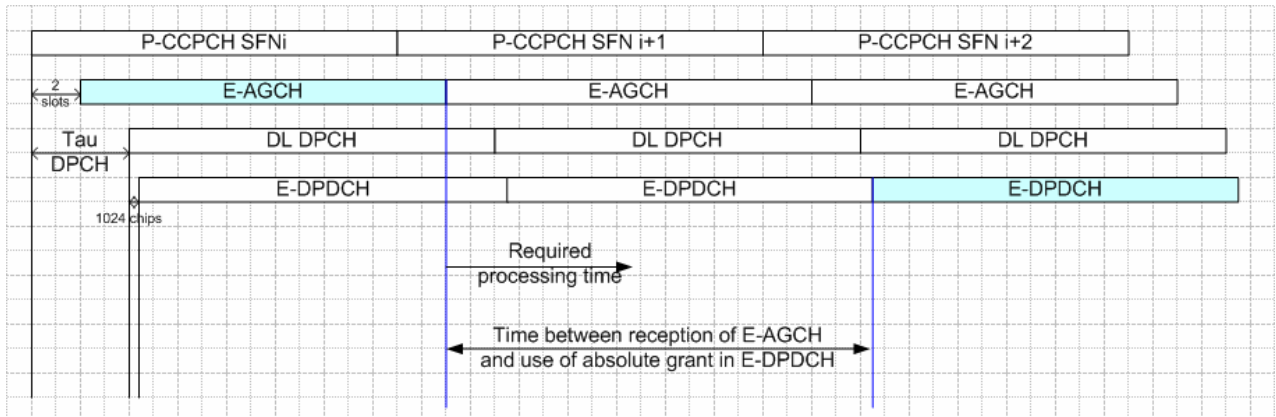


Figure 17 Timing of E-AGCH, 10 ms TTI, *s*=1

Figure 18 shows an example for the timing with *s*=0.

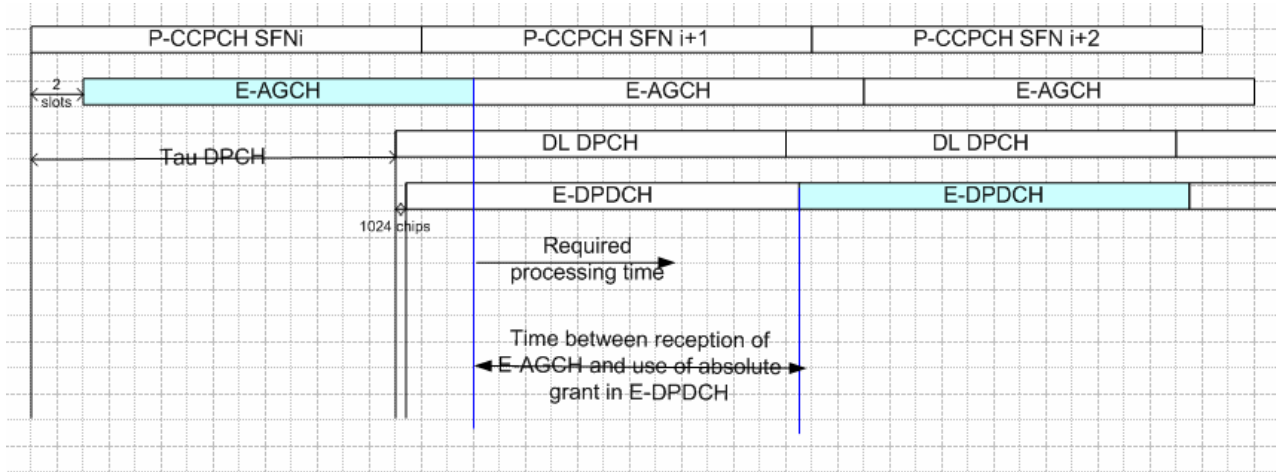


Figure 18 Timing of E-AGCH, 10 ms TTI, s=0

E-AGCH, 2 ms TTI

The UE uses the control data received in the E-AGCH sub-frame j associated to SFN i in the E-DPDCH sub-frame t associated with SFN $i+s$, with s and t equal to:

$$s = \left\lceil \frac{\left\lceil \frac{30j + 100 - (\tau_{DPCH,n}/256)}{30} \right\rceil}{5} \right\rceil \quad t = \left\lceil \frac{30j + 100 - (\tau_{DPCH,n}/256) - 150s}{30} \right\rceil$$

Let's assume $j = 1$, then for low values of τ_{DPCH} , $s=1$. If τ_{DPCH} is further increasing and $\tau_{DPCH} \geq 10 * 256$ chips, s gets 0.

Figure 19 shows an example for the timing with $\tau_{DPCH} = 0$, $j = 1$, $s=1$, $t=0$.

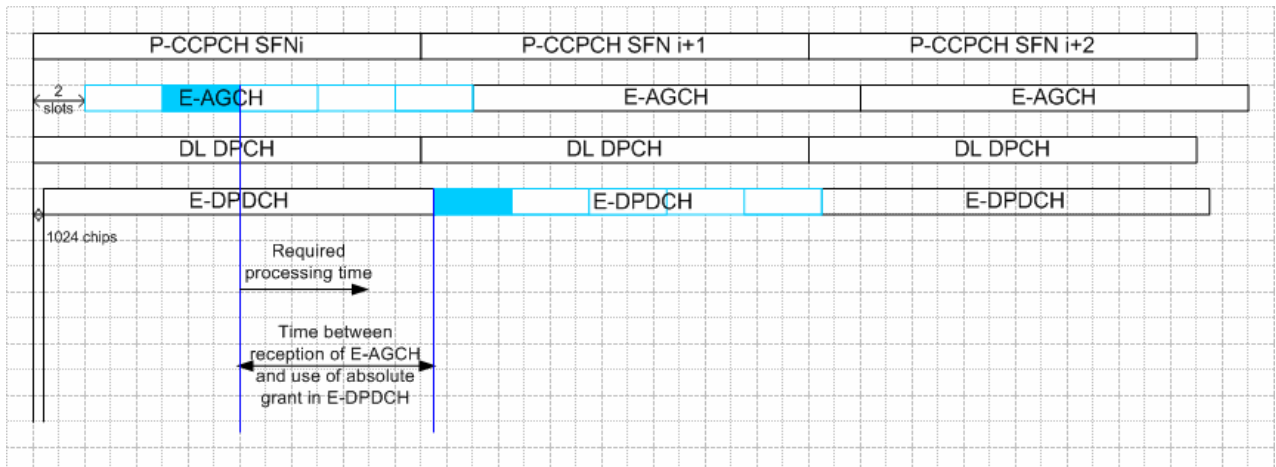


Figure 19 Timing of E-AGCH, 2 ms TTI, s=1, j=1

Figure 20 shows an example for the timing with $\tau_{DPCH} = 40 * 256$ chips, $j = 1$, $s = 0$, $t = 3$.

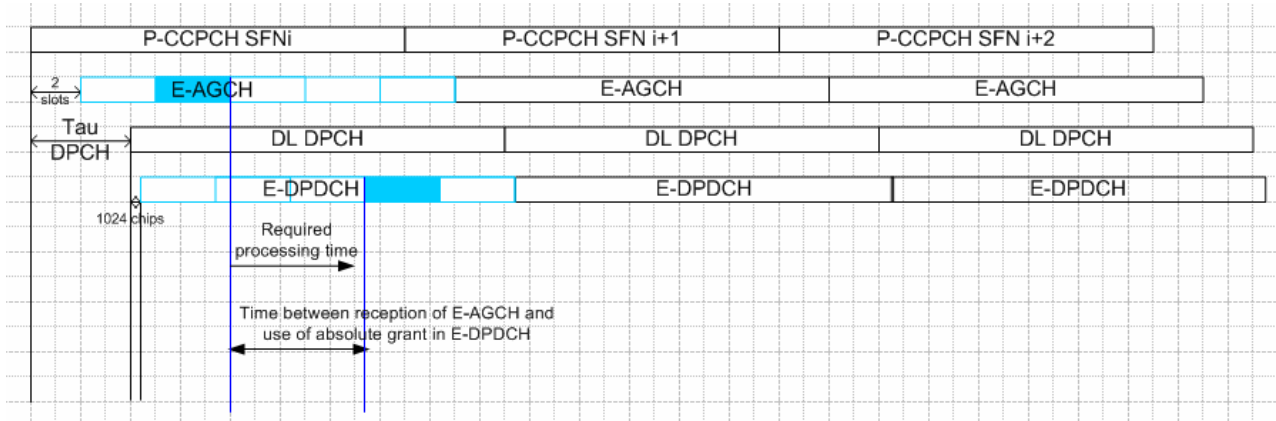


Figure 20 Timing of E-AGCH, 2 ms TTI, s=0, j=1

Timing of E-RGCH

The timing of the E-RGCH depends on whether 2 ms TTI or 10 ms TTI is applied and on whether E-RGCH is transmitted from serving radio link set or from non-serving radio link.

E-RGCH in Serving Radio Link Set, 10 ms TTI

The UE uses the relative grant received in the E-RGCH frame associated with SFN i in the E-DPDCH frame associated with SFN i + 1. The timing of the E-RGCHs sent from serving radio link set is dependent on τ_{DPCH} and offset from P-CCPCH frame boundary by τ_{E-RGCH} :

$$\tau_{E-RGCH,n} = 5120 + 7680 \times \left\lfloor \frac{(\tau_{DPCH,n}/256) - 70}{30} \right\rfloor$$

Figure 21 shows an example with $\tau_{DPCH} = 0$, resulting in $\tau_{E-RGCH} = - 7$ slots. Note that when E-RGCH is part of the serving radio link set, it is only transmitted during 12 slots.

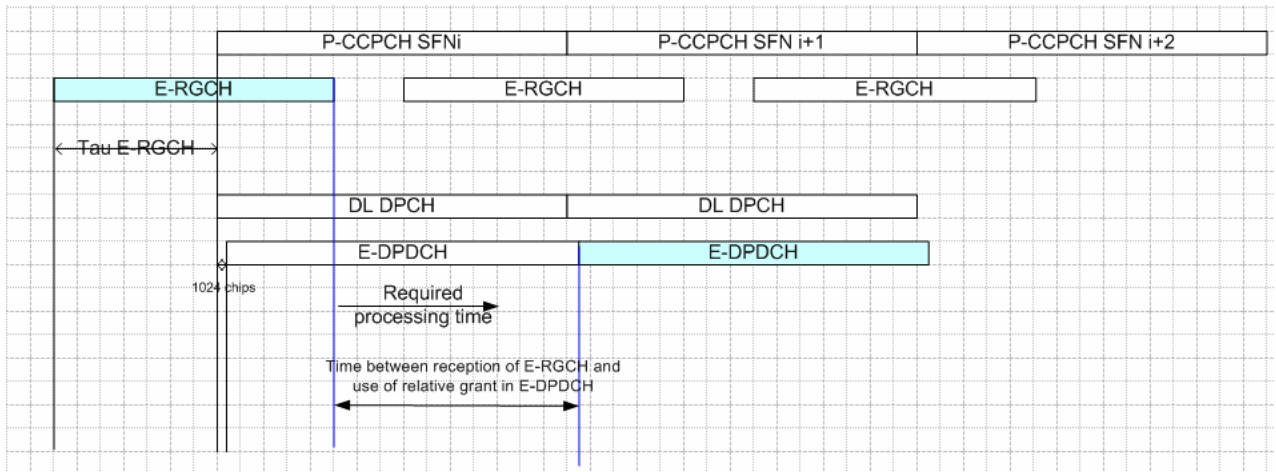


Figure 21 Timing of E-RGCH of serving RLS, 10 ms TTI

With increasing τ_{DPCH} , the offset of E-RGCH relative to P-CCPCH becomes positive. Figure 22 shows an example with $\tau_{DPCH} = 100 * 256$ chips, resulting in $\tau_{E-RGCH} = +5$ slots.

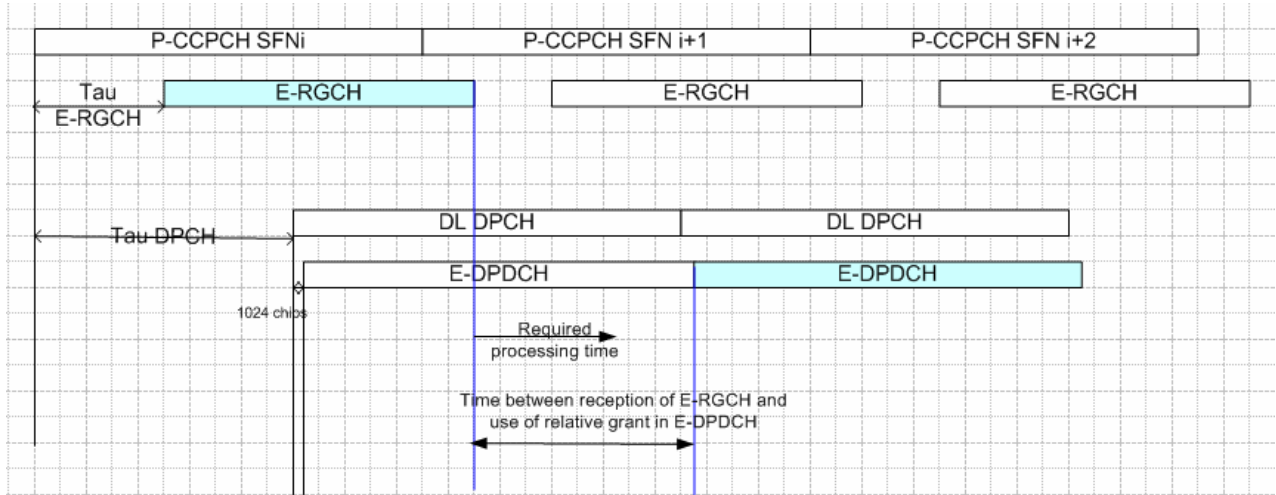


Figure 22 Timing of E-RGCH of serving RLS, 10 ms TTI

An overview of the timing possibilities is given in table 11.

Table 11 Timing of E-RGCH of serving RLS, 10 ms TTI, overview

TTI = 10 ms	
DL-DPCH relative to P-CCPCH (τ_{DPCH})	E-RGCH relative to P-CCPCH (τ_{E-RGCH})
$0 \leq \tau_{DPCH} < 10 \cdot 256$ chips	-7 slots
$10 \cdot 256 \leq \tau_{DPCH} < 40 \cdot 256$ chips	-4 slots
$40 \cdot 256 \leq \tau_{DPCH} < 70 \cdot 256$ chips	-1 slots
$70 \cdot 256 \leq \tau_{DPCH} < 100 \cdot 256$ chips	2 slots
$100 \cdot 256 \leq \tau_{DPCH} < 130 \cdot 256$ chips	5 slots
$130 \cdot 256 \leq \tau_{DPCH} < 150 \cdot 256$ chips	8 slots

E-RGCH in Serving Radio Link Set, 2 ms TTI

The UE uses the relative grant received in the sub-frame j of E-RGCH frame associated with SFN i in the E-DPDCH sub-frame j associated with SFN i + 1. The timing of the E-RGCHs sent from serving radio link set is dependent on τ_{DPCH} and offset from P-CCPCH frame boundary by τ_{E-RGCH} :

$$\tau_{E-RGCH,n} = 5120 + 7680 \times \left\lfloor \frac{(\tau_{DPCH,n}/256) + 50}{30} \right\rfloor$$

Figure 23 shows an example with $\tau_{DPCH} = 0$ and j = 1, resulting in $\tau_{E-RGCH} = +5$ slots

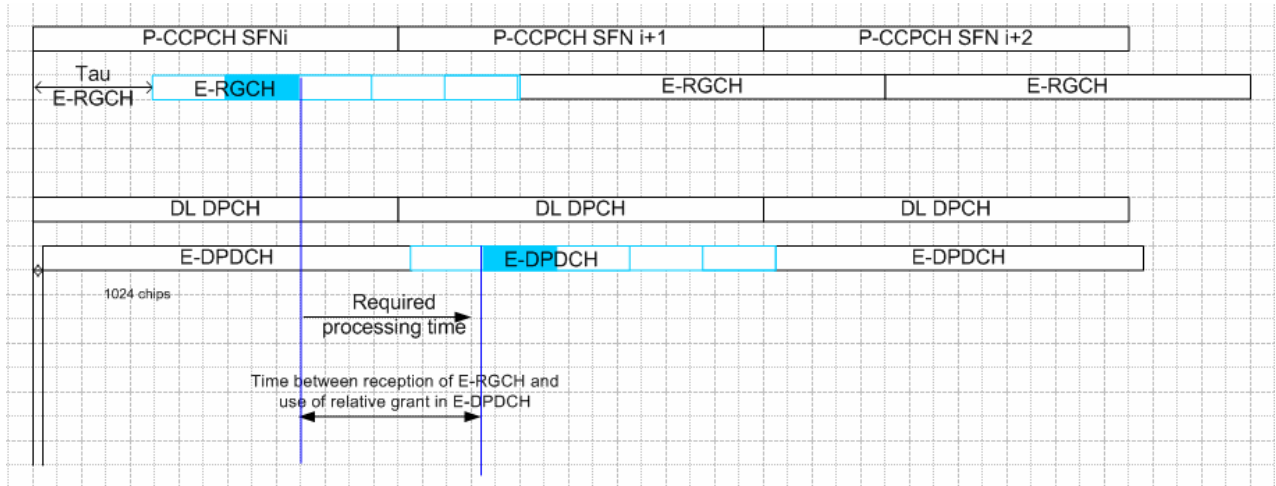


Figure 23 Timing of E-RGCH of serving RLS, 2 ms TTI, $j=1$

With increasing τ_{DPCH} , the offset of E-RGCH relative to P-CCPCH becomes larger. Figure 24 shows an example with $\tau_{DPCH} = 100 * 256$ chips, resulting in $\tau_{E-RGCH} = +17$ slots

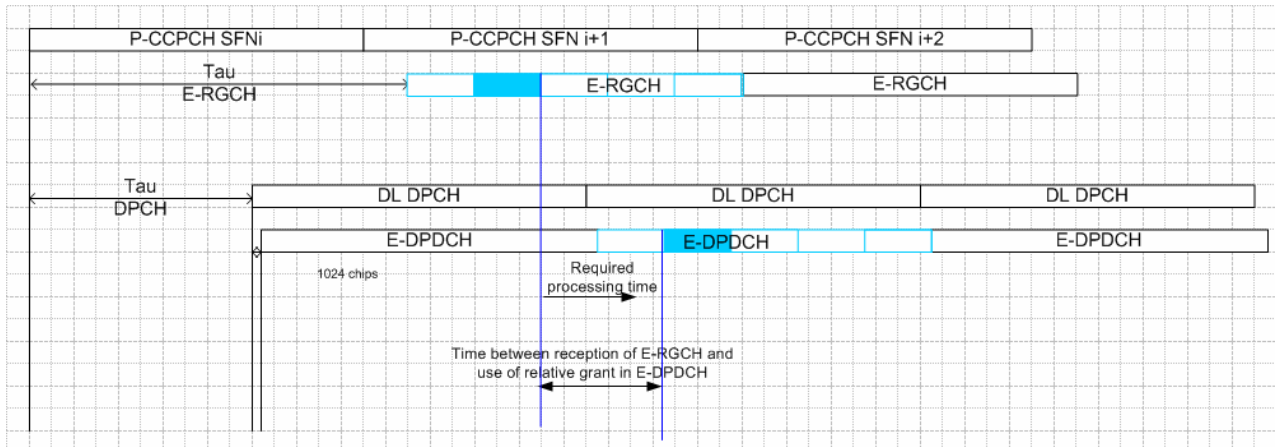


Figure 24 Timing of E-RGCH of serving RLS, 2 ms TTI, $j=1$

An overview of the timing possibilities is given in table 12.

Table 12 Timing of E-RGCH of serving RLS, 2 ms TTI, overview

TTI = 2 ms	
DL-DPCH relative to P-CCPCH (τ_{DPCH})	E-RGCH relative to P-CCPCH (τ_{E-RGCH})
$0 \leq \tau_{DPCH} < 10 * 256$ chips	5 slots
$10 * 256 \leq \tau_{DPCH} < 40 * 256$ chips	8 slots
$40 * 256 \leq \tau_{DPCH} < 70 * 256$ chips	11 slots
$70 * 256 \leq \tau_{DPCH} < 100 * 256$ chips	14 slots
$100 * 256 \leq \tau_{DPCH} < 130 * 256$ chips	17 slots
$130 * 256 \leq \tau_{DPCH} < 150 * 256$ chips	20 slots

E-RGCH from Non-Serving Radio Link, 10 ms TTI

In cells that are not part of serving RLS, the E-RGCH is transmitted with 5120 chips offset compared to P-CCPCH frame boundary. Since relative grants from non-serving radio links are used for load control only, processing requirements are more relaxed compared to E-AGCH.

The UE uses the control data received in the E-RGCH frame associated to SFN *i* in the E-DPDCH frame associated with SFN *i+1+s*, with *s* equal to:

$$s = \left\lceil \frac{160 - (\tau_{DPCH,n} / 256)}{150} \right\rceil$$

For low values of τ_{DPCH} , $s=2$. If τ_{DPCH} is further increasing and $\tau_{DPCH} \geq 10 * 256$ chips, s gets 1.

Figure 25 shows an example timing from UE perspective with $s=2$ and $\tau_{DPCH} = 0$, and figure 26 shows an example timing with $s=1$ and $\tau_{DPCH} = 40 * 256$ chips.

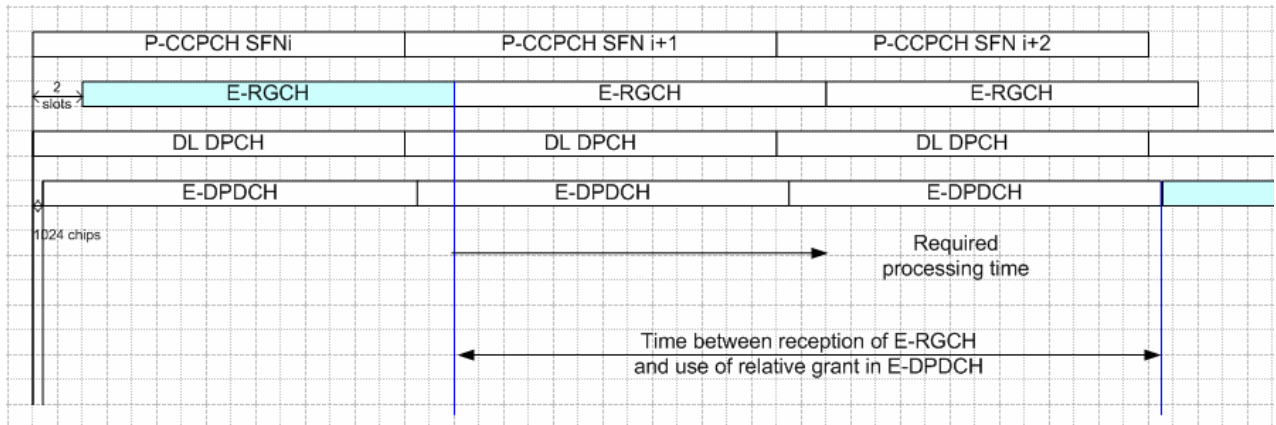


Figure 25 Timing of E-RGCH from non-serving cell, 10 ms TTI, $s=2$

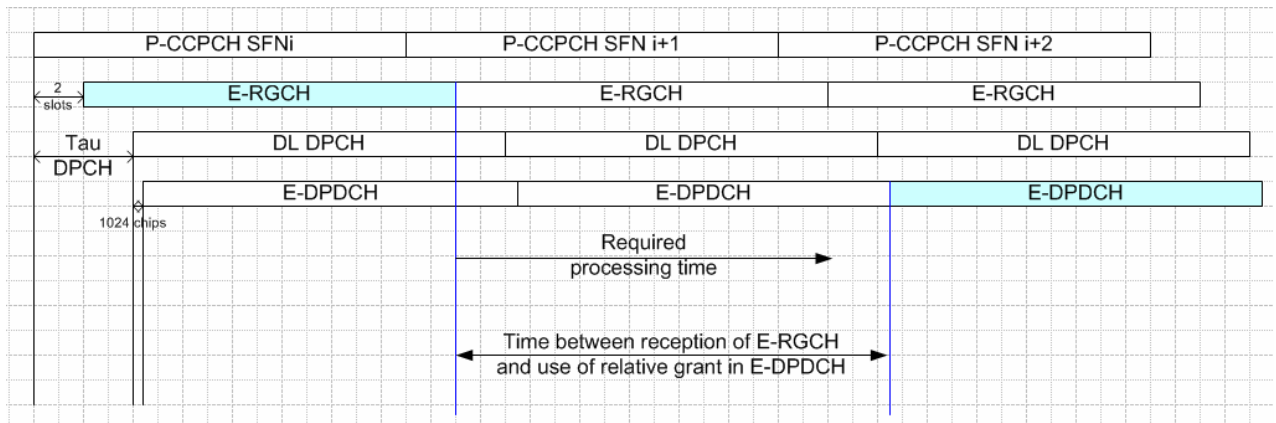


Figure 26 Timing of E-RGCH from non-serving cell, 10 ms TTI, $s=1$

E-RGCH from Non-Serving Radio Link, 2 ms TTI

For the 2 ms TTI, the UE uses control data received in **E-RGCH** associated with SFN_i in the E-DPDCH sub-frame *t* of the radio frame with SFN_{i+1+s}, where

$$s = \left\lfloor \frac{\left\lceil \frac{160 - (\tau_{DPCH,n} / 256)}{30} \right\rceil}{5} \right\rfloor \quad t = \left\lceil \frac{160 - (\tau_{DPCH,n} / 256) - 150s}{30} \right\rceil$$

For low values of τ_{DPCH} , *s* takes the value 1. When $\tau_{DPCH} \geq 40 * 256$ chips, *s* will become equal to 0.

Calculating *t* will then determine the appropriate sub-frame where to apply the relative grant. Figures 27 and 28 show examples for timing with *s*=1 (in this case $\tau_{DPCH} = 0$ and *t*=1) and *s*=0 (in this case $\tau_{DPCH} = 40 * 256$ chips), respectively.

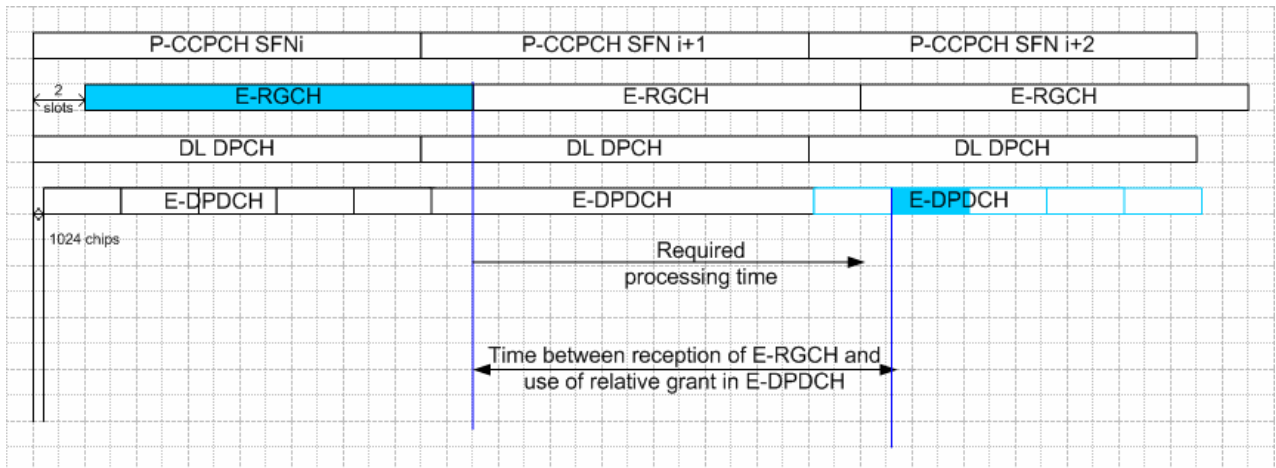


Figure 27 Timing of E-RGCH from non-serving cell, 2 ms TTI, *s*=1, *t*=1

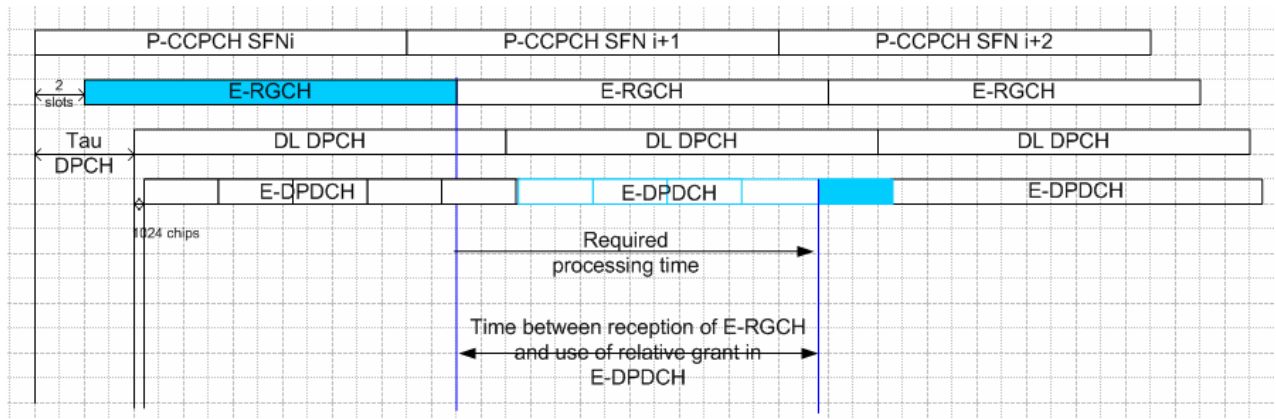


Figure 28 Timing of E-RGCH from non-serving cell, 2 ms TTI, *s*=0, *t*=4

5 Hybrid ARQ Protocol

The Hybrid ARQ (Automatic Repeat Request) Protocol is a retransmission protocol allowing the Node B to request retransmissions of incorrectly received data packets. Furthermore, the Node B can soft combine the retransmission with the original transmission to increase the likelihood that the packet can be decoded correctly.

ACK/NACK information is conveyed to the terminal on the E-HICH in the downlink.

In order to overcome the limitations of the Stop-and-Wait type protocol, Hybrid ARQ processes are introduced. By this, packets can be transmitted continuously from the UE, without requiring to wait for the ACK/NACK response from the network. In case of 10 ms TTI, 4 HARQ processes are configured (corresponding to 40 ms round trip time). In case of 2 ms TTI, 8 HARQ processes are configured (16 ms round trip time). This is illustrated in figure 29 for the 10 ms TTI case.

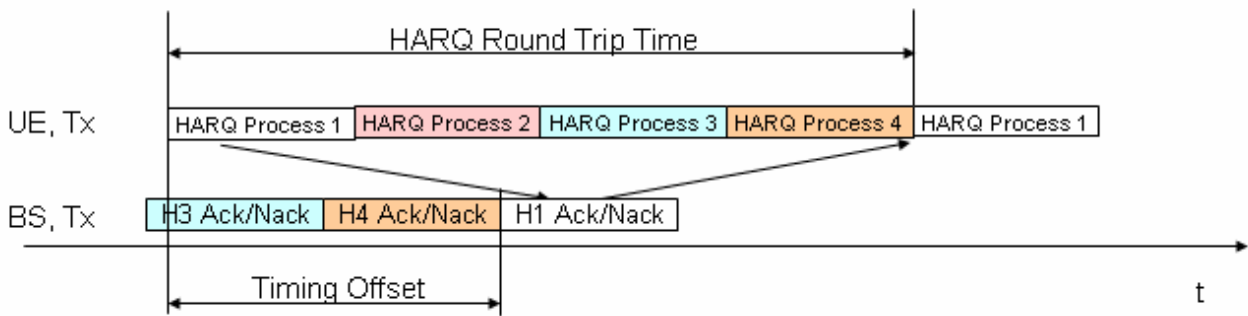


Figure 29 Handling of 4 HARQ Processes, 10 ms TTI

For each transmitted data packet, the UE is sending a retransmission sequence number (RSN) on E-DPCCH in a clearly specified way. The RSN is a 2 bit value. Therefore, after the 3rd retransmission, it is not incremented any more and the packets are all carrying RSN = 3, see figure 30.

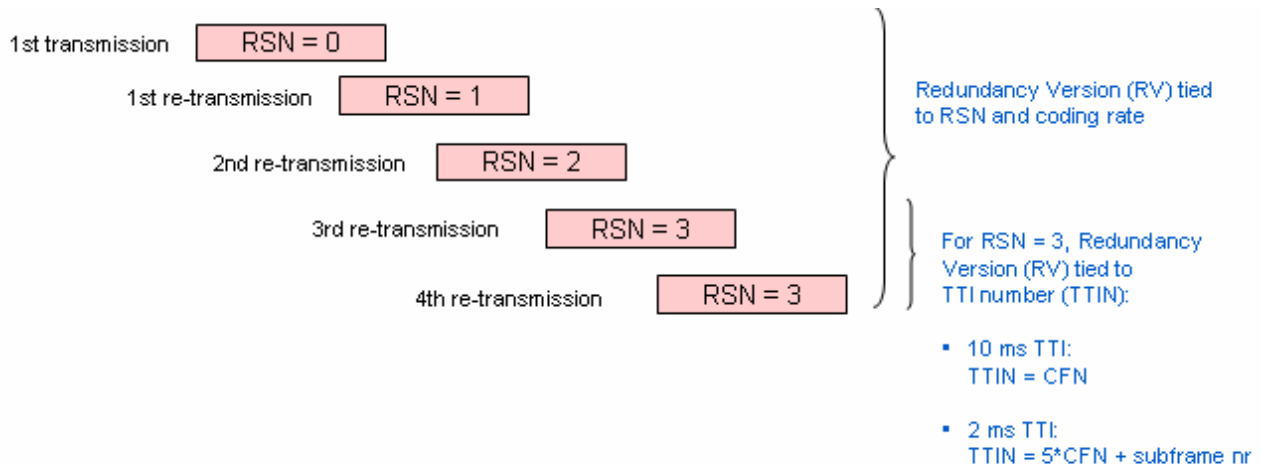


Figure 30 Selection of redundancy version depending on RSN and coding rate

To each retransmission level, a certain redundancy version is associated which is also influenced by the coding rate, and for RSN = 3 also by the TTI number. Figures 30 and 31 show the principle. Each redundancy version represents a certain *s* and *r* parameter combination. Together, *s* and *r* clearly define the selection of bits that can be transmitted on the air interface resource, i.e. the rate matching pattern. Due to this fixed rules, there is no need to signal the redundancy version in the uplink on E-DPCCH. Only the RSN is signaled on E-DPCCH, as well as the E-TFCI (used to derive the coding rate).

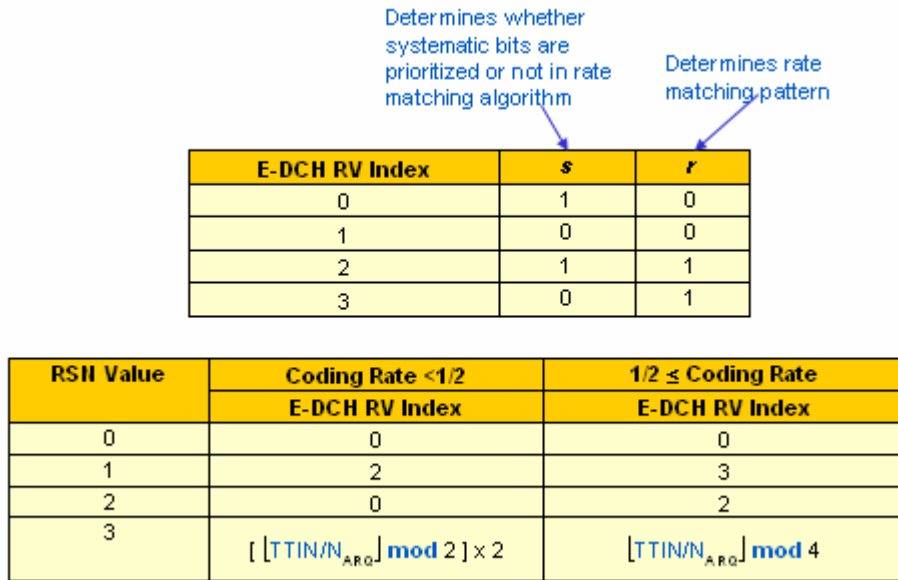


Figure 31 Selection of Redundancy Version [N_{ARQ} = Number of Hybrid ARQ Processes]

Note that instead of using the scheme depicted in figure 31, the network can also decide to always use redundancy version 0 (i.e. chase combining). This can be configured at call setup.

The maximum number of retransmissions depends on the HARQ profile configured by the network for a specific data flow (so-called “Mac-d flow”). Besides the power offset Δ_{harq} already introduced in section 3, the HARQ profile also consists of an attribute describing the maximum number of retransmissions. By this, the maximum latency and residual block error rate for this data flow can be adjusted.

Timing of E-HICH, 10 ms TTI

For 10 ms TTI, the UE associates control data of **E-HICH** frame SFNi to data transmitted in E-DPDCH frame SFNi-3. The E-HICH frame offset relative to P-CCPCH shall be $\tau_{E-HICH,n}$ chips with

$$\tau_{E-HICH,n} = 5120 + 7680 \times \left\lfloor \frac{(\tau_{DPCH,n}/256) - 70}{30} \right\rfloor$$

Possible values for τ_{E-HICH} relative to the P-CCPCH are: -7, -4, -1, 2, 5, 8 slots, see table 13.

Table 13 Timing of E-HICH, 10 ms TTI, overview

TTI = 10 ms	
DL-DPCH relative to P-CCPCH (τ_{DPCH})	E-HICH relative to P-CCPCH (τ_{E-HICH})
$0 \leq \tau_{DPCH} < 10 \cdot 256$ chips	-7 slots
$10 \leq \tau_{DPCH} < 40 \cdot 256$ chips	-4 slots
$40 \leq \tau_{DPCH} < 70 \cdot 256$ chips	-1 slots
$70 \leq \tau_{DPCH} < 100 \cdot 256$ chips	2 slots
$100 \leq \tau_{DPCH} < 130 \cdot 256$ chips	5 slots
$130 \leq \tau_{DPCH} < 150 \cdot 256$ chips	8 slots

Timing of E-HICH, 2 ms TTI

For 2 ms TTI, UE associates control data of **E-HICH** sub-frame j in SFNi to E-DPDCH sub-frame t / SFN $i-s$ where

$$s = 1 - \lfloor j/3 \rfloor \qquad t = (j + 2) \bmod 5$$

When the E-DCH TTI is 2 ms, the E-HICH frame offset relative to P-CCPCH shall be $\tau_{E-HICH,n}$ chips with

$$\tau_{E-HICH,n} = 5120 + 7680 \times \left\lfloor \frac{(\tau_{DPCH,n}/256) + 50}{30} \right\rfloor$$

Possible values for τ_{E-HICH} relative to the P-CCPCH are: 5, 8, 11, 14, 17, 20 slots, see table 14.

Table 14 Timing of E-HICH, 2 ms TTI, overview

TTI = 2 ms	
DL-DPCH relative to P-CCPCH (τ_{DPCH})	E-HICH relative to P-CCPCH (τ_{E-HICH})
$0 \leq \tau_{DPCH} < 10 \cdot 256$ chips	5 slots
$10 \leq \tau_{DPCH} < 40 \cdot 256$ chips	8 slots
$40 \leq \tau_{DPCH} < 70 \cdot 256$ chips	11 slots
$70 \leq \tau_{DPCH} < 100 \cdot 256$ chips	14 slots
$100 \leq \tau_{DPCH} < 130 \cdot 256$ chips	17 slots
$130 \leq \tau_{DPCH} < 150 \cdot 256$ chips	20 slots

6 HSUPA UE Categories

As for HSDPA, there are different UE categories defined for HSUPA. They reflect different levels of implementation complexity. The categories differ in terms of the maximum number of E-DCH codes, the minimum spreading factor, the transmission time interval, and the maximum transport block size supported. The maximum transport block size and the transmission time interval supported result in a maximum data rate capability for this terminal category as shown in table 15.

Table 15 UE Categories for HSUPA

E-DCH category	Maximum number of E-DCH codes transmitted	Minimum spreading factor	TTI	Maximum number of bits of an E-DCH transport block transmitted within an E-DCH TTI	Data Rate
Category 1	1	SF4	10 ms only	7110	0.71 Mbps
Category 2	2	SF4	10 ms	14484	1.45 Mbps
Category 2	2	SF4	2 ms	2798	1.4 Mbps
Category 3	2	SF4	10 ms only	14484	1.45 Mbps
Category 4	2	SF2	10 ms	20000	2 Mbps
Category 4	2	SF2	2 ms	5772	2.89 Mbps
Category 5	2	SF2	10 ms only	20000	2 Mbps
Category 6	4	SF2	10 ms	20000	2 Mbps
Category 6	4	SF2	2 ms	11484	5.74 Mbps

NOTE: When 4 codes are transmitted in parallel, two codes shall be transmitted with SF2 and two with SF4

7 Abbreviations

3GPP	3rd Generation Partnership Project
ACK	Acknowledgement
ARQ	Automatic Repeat Request
BLER	Block Error Rate
CFN	Connection Frame Number
CRC	Cyclic Redundancy Check
CRNC	Controlling Radio Network Controller
DCCH	Dedicated Control Channel
DTCH	Dedicated Traffic Channel
DPCH	Dedicated Physical Channel
DPCCH	Dedicated Physical Control Channel

HSUPA

DPDCH	Dedicated Physical Data Channel
DTX	Discontinuous Transmission
E-AGCH	E-DCH Absolute Grant Channel
E-DCH	Enhanced Dedicated Channel
E-DPCCH	E-DCH Dedicated Physical Control Channel
E-DPDCH	E-DCH Dedicated Physical Data Channel
E-HICH	E-DCH Hybrid ARQ Indicator Channel
E-RGCH	E-DCH Relative Grant Channel
E-RNTI	E-DCH Radio Network Temporary Identifier
E-TFCI	E-DCH Transport Format Combination Indicator
EUL	Enhanced Uplink
FDD	Frequency Division Duplex
F-DPCH	Fractional Dedicated Physical Channel
FP	Frame Protocol
HARQ	Hybrid Automatic Repeat Request
HSDPA	High Speed Downlink Packet Access
HS-DSCH	High Speed Downlink Shared Channel
HS-DPCCH	High Speed Dedicated Physical Control Channel
HSUPA	High Speed Uplink Packet Access
MAC	Medium Access Control
NACK	Negative Acknowledgement
PHY	Physical Layer
PO	Power Offset
QPSK	Quadrature Phase Shift Keying
PDU	Protocol Data Unit
RLC	Radio Link Control
RRC	Radio Resource Control
RSN	Retransmission Sequence Number
RV	Redundancy Version
SF	Spreading Factor
SG	Serving Grant
SRNC	Serving Radio Network Controller
TFC	Transport Format Combination
TFCI	Transport Format Combination Indicator
TPC	Transmit Power Control
TS	Technical Specification
TTI	Transmission Time Interval
TTIN	TTI Number

TNL	Transport Network Layer
UE	User Equipment
UMTS	Universal Mobile Telecommunications System
WCDMA	Wideband Code Division Multiple Access

8 Additional Information

This application note are updated from time to time. Please visit the website [1MA94](#) in order to download new versions.

Please send any comments or suggestions about this application note to TM-Applications@rsd.rohde-schwarz.com.

9 References

- [1] Application Note 1MA82; HSDPA Test and Measurement Requirements, Rohde & Schwarz
- [2] 3GPP TS 25.211; Physical channels and mapping of transport channels onto physical channels (FDD) (Release 6)
- [3] 3GPP TS 25.213; Spreading and Modulation (FDD) (Release 6)
- [4] 3GPP TS 25.212; Multiplexing and Channel Coding (FDD) (Release 6)
- [5] 3GPP TS 25.214; Physical layer procedures (FDD) (Release 6)
- [6] 3GPP TS 25.321; Medium Access Control (MAC) protocol specification (Release 6)

10 Ordering Information

Vector Signal Generator

R&S® SMU200A		1141.2005.02
R&S® SMU-B102	Frequency range 100 KHz to 2.2GHz for 1st RF Path	1141.8503.02
R&S® SMU-B103	Frequency range 100 KHz to 3GHz for 1st RF Path	1141.8603.02
R&S® SMU-B104	Frequency range 100 KHz to 4GHz for 1st RF Path	1141.8703.02
R&S® SMU-B106	Frequency range 100 KHz to 6 GHz for 1st RF Path	1141.8803.02
R&S® SMU-B202	Frequency range 100 KHz to 2.2 GHz for 2nd RF Path	1141.9400.02
R&S® SMU-B203	Frequency range 100 KHz to 3 GHz for 2nd RF Path	1141.9500.02
R&S® SMU-B10	Baseband Generator with digital modulation (realtime) and ARB (64MSamples)	1141.7007.02
R&S® SMU-B11	Baseband Generator with digital modulation (realtime) and ARB (16MSamples)	1159.8411.02
R&S® SMU-B13	Baseband Main Module	1141.8003.02
R&S® SMU-K42	Digital Standard 3GPP FDD	1160.7909.02
R&S® SMU-K45	3GPP FDD HSUPA	1161.0666.02

Signal Analyzers, Spectrum Analyzers and Options

R&S® FSP3	9 kHz to 3 GHz	1164.4391.03
R&S® FSP7	9 kHz to 7 GHz	1164.4391.07
R&S® FSP13	9 kHz to 13 GHz	1164.4391.13
R&S® FSP30	9 kHz to 30 GHz	1164.4391.30
R&S® FSP40	9 kHz to 40 GHz	1164.4391.40
R&S® FSQ3	20 Hz to 3.6 GHz	1155.5001.03
R&S® FSQ8	20 Hz to 8 GHz	1155.5001.08
R&S® FSQ26	20 Hz to 26,5 GHz	1155.5001.26
R&S® FSQ40	20 Hz to 40 GHz	1155.5001.40
R&S® FSU3	20 Hz to 3.6 GHz	1166.1660.03
R&S® FSU8	20 Hz to 8 GHz	1166.1660.08
R&S® FSU26	20 Hz to 26.5 GHz	1166.1660.26
R&S® FSU46	20 Hz to 46 GHz	1166.1660.46
R&S® FSU50	20 Hz to 50 GHz	1166.1660.50
R&S® FS-K72	Application firmware 3GPP-FDD BTS transmitter test for FSMR, FSP, FSU, FSQ	1154.7000.02
R&S® FS-K73	Application Firmware 3GPP-FDD UE Transmitter Test for FSMR, FSP, FSU, FSQ	1154.7252.02
R&S® FS-K74	3GPP HSDPA base station test application firmware for FSMR, FSU, FSP, FSQ	1300.7156.02

Protocol Tester

R&S® CRTU-W		1140.0509.02
R&S® CRTU-M		1140.2101.02
R&S® CRTU-WA01	HSDPA/HSUPA Layer 1 Test Software	1166.0106.02



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