

Rohde & Schwarz Products: FSP, FSQ, FSU, FS-K72, FS-K73, FS-K74, SMU200A, SMATE200A, SMJ100A, SMU-K43, SMATE-K43, SMJ-K43, SMU-K45, SMATE-K45, SMJ-K45, AFQ100A, WinIQSIM2, CMU200, CMU-K64, CMU-K60, CMU-K56

## HSDPA & HSUPA

### Challenges for UE Power Amplifier Design

#### Application Note

This Application Note describes the HSDPA and HSUPA uplink channel structure. Challenges for UE power amplifier design are outlined, and guidelines how to use R&S measurement equipment for testing UE power amplifiers are provided.



## Contents

1	Overview .....	3
2	HSDPA Uplink Design.....	5
3	HSUPA Uplink Design.....	14
4	Basic Test Setups with R&S Instruments.....	26
5	Abbreviations.....	45
6	Additional Information .....	47
7	References.....	47
8	Ordering information .....	48

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 I/Q Modulation Generator R&S® AFQ100A is referred to as the AFQ.
- The Spectrum Analyzers R&S® FSP and FSU are referred to as FSP and FSU.
- The Signal Analyzer R&S® FSQ is referred to as the FSQ.
- FSP, FSU and FSQ in general is referred to as the FSx.
- The Universal Radio Communication Tester R&S® CMU200 is referred to as the CMU200.

### 1 Overview

**High Speed Downlink Packet Access** (HSDPA) is part of 3GPP release 5 of WCDMA 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.

With HSDPA, new physical and transport channels are introduced on the air interface. Besides 2 new downlink physical channels for transmission of user data and control information, the **High Speed Dedicated Physical Control Channel (HS-DPCCH)** was introduced as a new **uplink** code channel for control purposes.

The HS-DPCCH puts severe requirements on power amplifier design for HSDPA terminals. Besides being the 3<sup>rd</sup> uplink code channel, the HS-DPCCH is not continuously transmitted and is not necessarily time aligned with the other WCDMA uplink channels. As a result, varying power relations to the dedicated uplink channels (DPCCH and DPDCH) are obtained.

**High Speed Uplink Packet Access** (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.

Besides 3 new downlink physical channels for control purposes, HSUPA requires the introduction of 2 new uplink channels. The **Enhanced Dedicated Physical Data Channel (E-DPDCH)** is used for uplink data transmission, and the **Enhanced Dedicated Physical Control Channel (E-DPCCH)** is used for conveying associated control information.

This Application Note describes the HSDPA and HSUPA uplink channel structure. Challenges for UE power amplifier design are outlined, and guidelines how to use R&S measurement equipment for testing UE power amplifiers are provided.

## ***HSDPA & HSUPA: Challenges for UE Power Amplifier Design***

**Chapter 2** focuses on HSDPA and explains the structure of the HS-DPCCH as well as timing relations and power settings. Major challenges of the HS-DPCCH channel for UE power amplifier design are outlined. Basic test and measurement requirements relevant for HS-DPCCH as defined in 3GPP are described.

**Chapter 3** focuses on HSUPA and explains the structure of E-DPDCH and E-DPCCH, as well as their impact on UE power amplifier design. T&M requirements according to 3GPP are outlined.

**Chapter 4** explains basic test setups related to HSDPA and HSUPA with the help of Rohde & Schwarz measurement equipment. It is explained how to generate and analyze HS-DPCCH (manually or with the help of a complimentary demo software), and E-DPCCH / E-DPDCH.

**Chapters 5 to 8** provide additional information including literature references.

This application note assumes basic knowledge of HSDPA and HSUPA technologies as outlined in application notes 1MA82 [1] and 1MA94 [2].

## 2 HSDPA Uplink Design

### HS-DPCCH Physical Channel Structure

The HS-DPCCH is an uplink physical channel with fixed spreading factor 256 [3]. It is used to convey user feedback about channel quality (CQI = Channel Quality Indicator) as well as packet acknowledgements or negative acknowledgements (ACK or NACK). No user data is transmitted on the HS-DPCCH.

By using a separate code channel for the HS-DPCCH, backwards compatibility with release 99 is ensured.

The HS-DPCCH is based on a sub-frame structure, with one sub-frame consisting of 3 timeslots (= 2 ms). The packet ACK or NACK information is transmitted in the first timeslot of the sub-frame, and the CQI value is transmitted in the second and third timeslot of the sub-frame.

The structure of the HS-DPCCH is shown in figure 1.

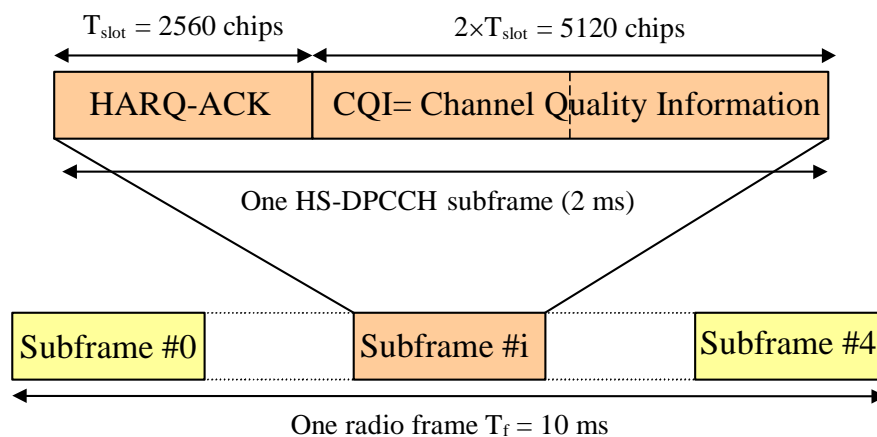


Figure 1 – Structure of HS-DPCCH

The HS-DPCCH is not transmitted continuously. DTX (i.e. no transmission) can occur on ACK/NACK and CQI fields independently from one another. ACK/NACK is only transmitted in case a packet on the downlink HSDPA user data channel (HS-PDSCH, High Speed Physical Downlink Shared Channel) was received by the UE before. CQI is transmitted according to the CQI feedback cycle  $k$  parameter which is configured by higher layers, ranging from 0 ms, 2 ms, ..., up to 160 ms.

The HS-DPCCH cannot exist as a stand-alone channel, but it always exists together with a Dedicated Physical Control Channel (DPCCH) and possibly

## HSDPA & HSUPA: Challenges for UE Power Amplifier Design

one or more Dedicated Physical Data Channels (DPDCH). All these channels are IQ multiplexed in the uplink [5]. The HS-DPCCH is either mapped on the I domain or on the Q domain, depending on the number of DPDCHs present. If there is an odd number of DPDCHs, the HS-DPCCH is mapped on the Q domain. If there is an even number of DPDCHs, the HS-DPCCH is mapped on the I domain. This is illustrated in figure 2.

The channels are spread individually and scaled by gain factors (see below for more details on gain factor setting).

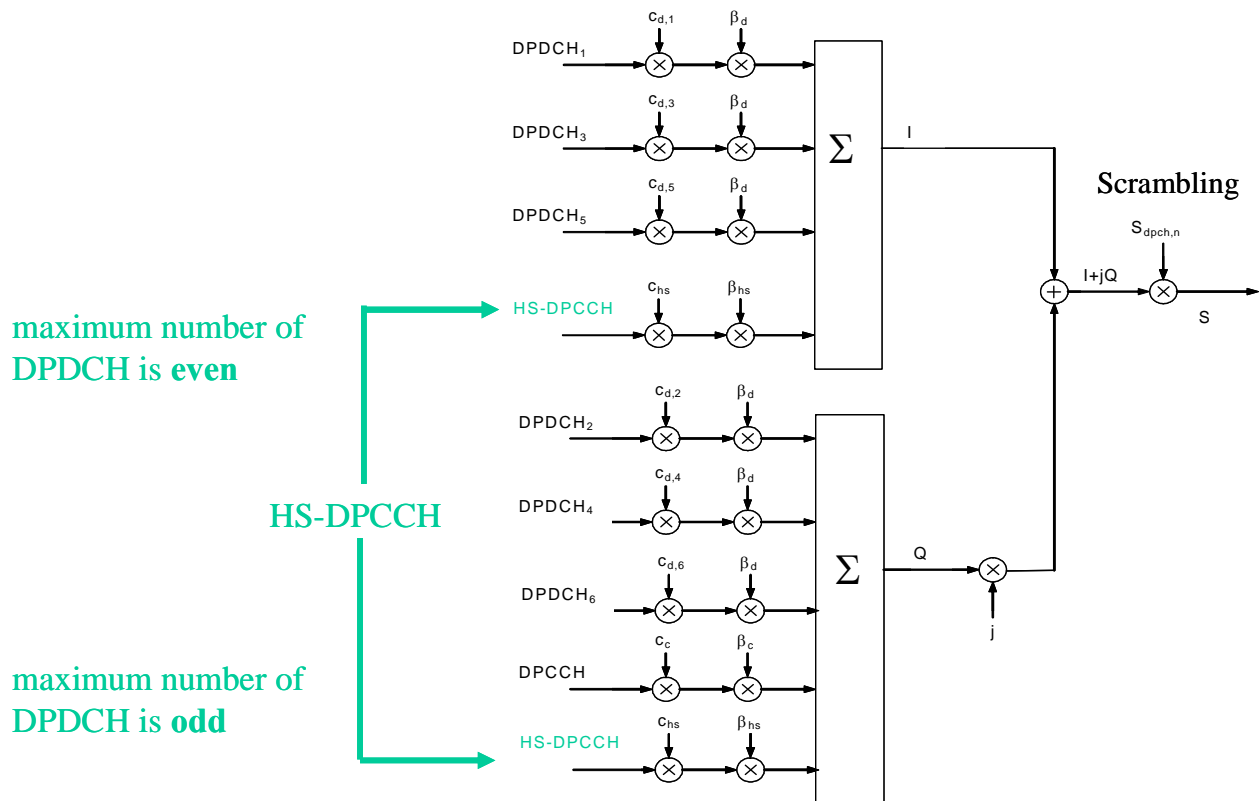


Figure 2 – Spreading for Uplink DPCCH, DPDCHs and HS-DPCCH

### Uplink Timing Relations

The HS-DPCCH is not necessarily slot aligned with the uplink DPCH.

In order to understand the timing of the HS-DPCCH, it is important to remember the timing relations of the HSDPA related channels in the downlink, High Speed Shared Control Channel (HS-SCCH) and High Speed Physical Downlink Shared Channel (HS-PDSCH). This is because the HS-DPCCH carries the ACK/NACK response for a packet with user data received within an HS-PDSCH sub-frame. Therefore, the timing of the HS-PDSCH directly influences the timing of the HS-DPCCH.

## HSDPA & HSUPA: Challenges for UE Power Amplifier Design

The start of the HS-SCCH which carries scheduling information for HS-PDSCH is aligned with the start of the P-CCPCH frames. The HS-PDSCH sub-frame associated to an HS-SCCH sub-frame starts  $t_{\text{HS-PDSCH}} = 2 \times T_{\text{slot}} = 5120$  chips after the start of this HS-SCCH sub-frame, see figure 3.

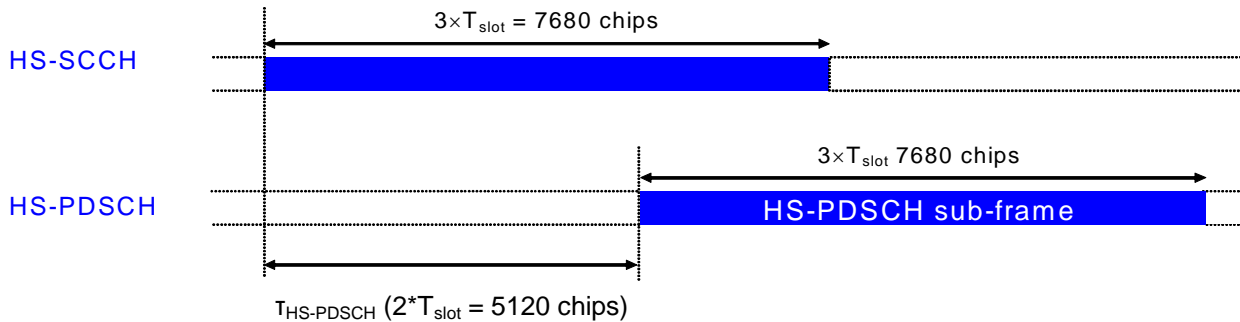


Figure 3 - Timing relation between the HS-SCCH and the associated HS-PDSCH

The downlink DPCH timing may be offset from the P-CCPCH frame timing with a multiple of 256 chips ( $T_{\text{dpch\_offset}}$ ), which is signaled by higher layers to the UE.

All downlink channels are received at the UE with a propagation delay. The UE has to decode the received HS-PDSCH packet and prepare an ACK or NACK for transmission on the HS-DPCCH. For this processing, 7.5 slots corresponding to 19200 chips are assumed as required processing time in the UE (figure 4).

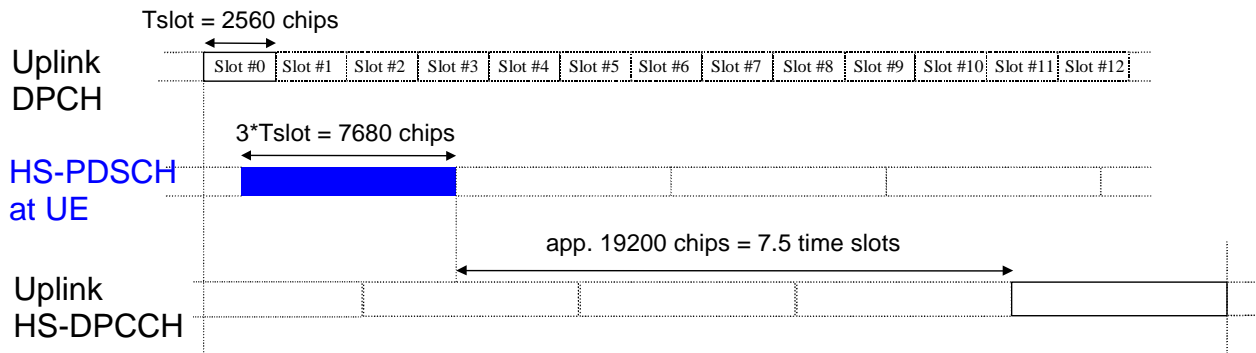


Figure 4 - Timing structure at the UE for HS-DPCCH control signaling

Figure 5 shows the resulting overall timing. The upper part of the figure shows the timing of the downlink channels at the Node B side. The lower part of the figure shows the timing at the UE side.  $TTX_{\text{diff}}$  is the difference in chips ( $TTX_{\text{diff}} = 0, 256, \dots, 38144$  chips) between the start of a HS-PDSCH transmission and the start of the related downlink DPCH frame.

## HSDPA & HSUPA: Challenges for UE Power Amplifier Design

Since there are 5 possible sub-frames for the HS-PDSCH within one radio frame, TTX\_diff can accordingly take one of a set of 5 possible values in a given scenario. TTX\_diff determines the transmit timing  $T_{UIDpch-HsDpcc}$  of the HS-DPCCH in relation to the uplink DPCH as shown in figure 5. For simplification, the parameter  $m = (TTX\_diff/256)+101$  has been introduced in specifications to express the transmit timing of the HS-DPCCH [3].

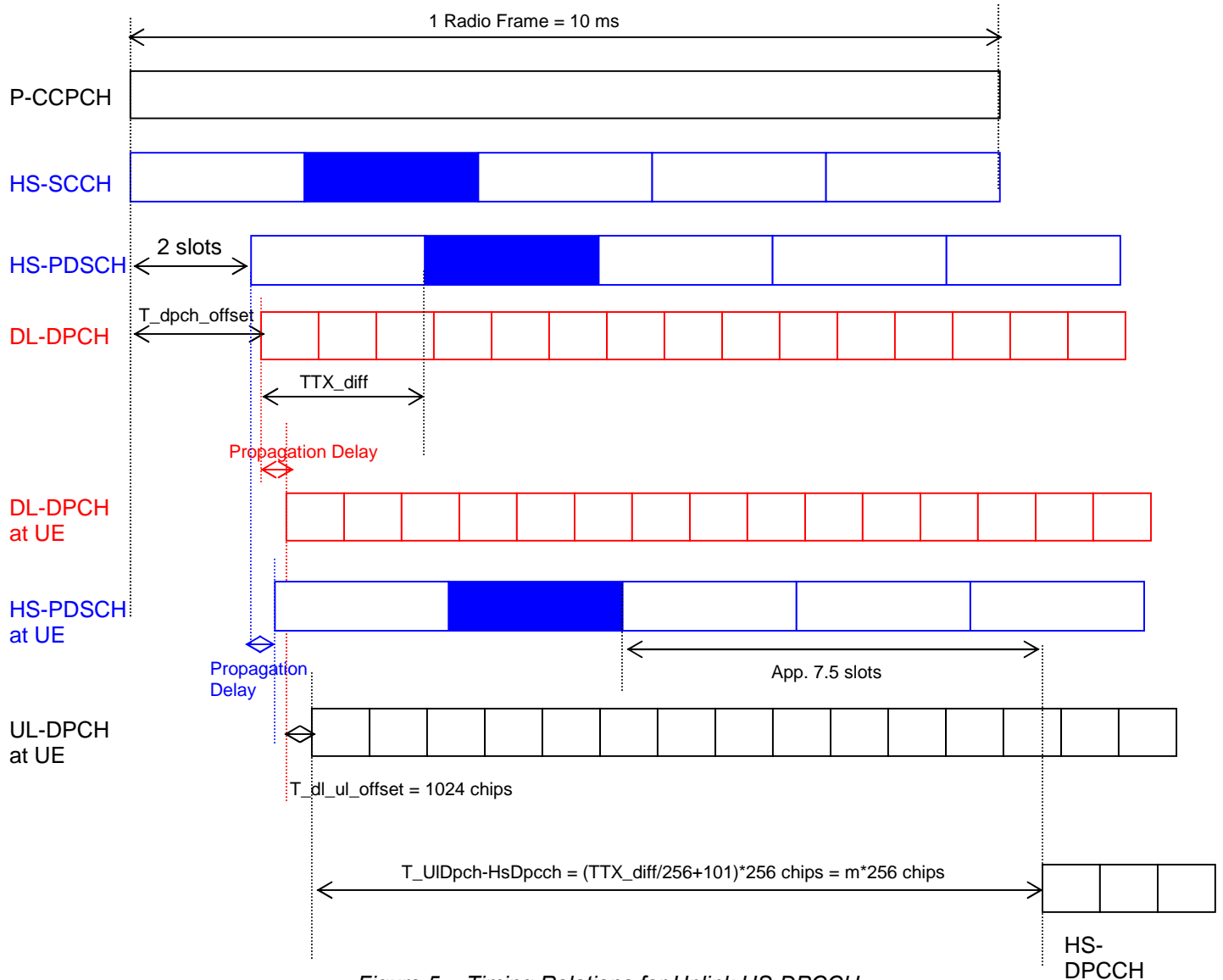


Figure 5 - Timing Relations for Uplink HS-DPCCH

The formula for  $m$  can be derived as follows:

$$m = TTX\_diff/256 + 101 = TTX\_diff/256 + (19200 \text{ chips} + 3 * 2560 \text{ chips} - 1024 \text{ chips}) / (256 \text{ chips})$$



It is important to remember that the setting of the DPCH frame offset ( $T_{dpch\_offset}$  in figure 5) influences the timing of the HS-DPCCH relative to the uplink DPCCH.

### HS-DPCCH Power Setting

The power of the HS-DPCCH is set in relation to the DPCCH. For this purpose, a power offset value  $\Delta_{HS-DPCCH}$  is applied by the UE on each HS-DPCCH timeslot. The UE derives this power offset from higher layer signaling as follows.

The power offset value  $\Delta_{HS-DPCCH}$  in a particular timeslot depends on whether ACK, NACK or CQI information is transmitted in this timeslot. Therefore, three different power offset values  $\Delta_{ACK}$ ,  $\Delta_{NACK}$ ,  $\Delta_{CQI}$  are signaled by higher layers to the UE. The UE sets the power offset  $\Delta_{HS-DPCCH}$  in a particular timeslot equal to  $\Delta_{ACK}$ ,  $\Delta_{NACK}$  or  $\Delta_{CQI}$ , depending on what is transmitted in this timeslot.

For  $\Delta_{ACK}$ ,  $\Delta_{NACK}$ ,  $\Delta_{CQI}$ , integer values 0..8 can be signaled by higher layers. These are then quantized in amplitude ratios according to table 1 taken from [5].

Table 1 - Quantization of power offset for HS-DPCCH

Signaling values for $\Delta_{ACK}$ , $\Delta_{NACK}$ , $\Delta_{CQI}$	Quantized amplitude ratios for $10^{\left(\frac{\Delta_{HS-DPCCH}}{20}\right)}$
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

The gain factor  $\beta_{hs}$  for non-compressed frames as referred to in figure 2 is defined as follows:

$$\beta_{hs} = \beta_c \cdot 10^{\left(\frac{\Delta_{HS-DPCCH}}{20}\right)}$$

## HSDPA & HSUPA: Challenges for UE Power Amplifier Design

$\beta_c$  is the gain factor valid for the uplink DPCCH. It is either signaled by higher layers to the UE, or computed according to [6]. The same holds for the gain factor  $\beta_d$  valid for the uplink DPDCH.

At every instant in time, at least one of the values  $\beta_c$  and  $\beta_d$  has the amplitude 1.0. The  $\beta_c$  and  $\beta_d$  values are quantized into 4 bit words. The quantization steps are given in table 2 taken from [5]:

Table 2 - Quantization of gain factors

Signaling values for $\beta_c$ and $\beta_d$	Quantized amplitude ratios $\beta_c$ and $\beta_d$
15	1.0
14	14/15
13	13/15
12	12/15
11	11/15
10	10/15
9	9/15
8	8/15
7	7/15
6	6/15
5	5/15
4	4/15
3	3/15
2	2/15
1	1/15
0	Switch off

The gain factors as derived by higher layer signaling are now used for scaling HS-DPCCH, DPDCH and DPCCH before transmission in the uplink, see figure 2.

In the case that the total UE transmit power after applying DPCCH power adjustments and gain factors would exceed the maximum allowed value, the UE shall apply additional scaling to the total transmit power so that it is equal to the maximum allowed power. This additional scaling shall be such that the power ratio between DPCCH and DPDCH and also DPCCH and HS-DPCCH remains as required. Any scaling shall only be applied or changed at a DPCCH slot boundary.

The minimum requirements for UE maximum output power are given in 3GPP TS 25.101 [7], and the related tests can be found in 3GPP TS 34.121 [12]. Please note that tests have been modified for release 6. This will be described in more detail below.

### **Impact of HS-DPCCH on UE Power Amplifier**

The HS-DPCCH as 3<sup>rd</sup> uplink code channel increases the Peak-to-Average Ratio (PAR) and therefore puts higher requirements on the linearity of UE power amplifiers. The standard foresees lower values for UE maximum output powers in the presence of HS-DPCCH. This was done in order to not aggravate linearity requirements on the UE power amplifiers compared to release 99. It has been demonstrated by simulations that the required power reduction is significantly different for different combinations of  $\beta_c$ ,  $\beta_d$  and  $\beta_{hs}$ , see e.g. [9], [10], [11]. Therefore, the allowed UE maximum output powers depend on the gain factor combinations. In order to avoid negative impact on uplink cell coverage, UE maximum output power reduction has only been introduced for those gain factor combinations that are most critical in terms of PAR increase.

The highest 99.9% PAR increase compared to a release 99 reference channel combination according to these simulations occurs for relations of  $\beta_c/\beta_d > 1$ . Besides the PAR increase, the output power probability function of the uplink signal needs to be regarded to evaluate the impact on the power amplifier. The simulations cited above have shown that in a signal with HS-DPCCH, the probability that power is above average power is much higher. Thus, the maximum output power reduction needs to be higher than the expected 99.9% PAR increase in order to meet the linearity requirements.

Obviously it is implementation dependent how a specific power amplifier copes with the linearity requirements, so it is crucial to verify the power amplifier performance in order to meet specification requirements, e.g. Adjacent Channel Leakage Ratio (ACLR).

### **UE Transmitter Tests according to 3GPP**

UE transmitters have to comply to test and measurement requirements as given in 3GPP specifications.

In 3GPP specification TS 34.121 [12], various new transmitter test cases for HS-DPCCH can be found:

## HSDPA & HSUPA: Challenges for UE Power Amplifier Design

- Test Case 5.2A: Maximum output power with HS-DPCCH (Release 5 only)
- Test Case 5.2AA: Maximum output power with HS-DPCCH (Release 6 and later)
- Test Case 5.7A: Transmit ON/OFF power, HS-DPCCH
- Test Case 5.9A: Spectrum Emission Mask with HS-DPCCH
- Test Case 5.10A: ACLR with HS-DPCCH
- Test Case 5.13.1A: Error Vector Magnitude (EVM) with HS-DPCCH
- [to be introduced: Phase discontinuity for HS-DPCCH, and UE Relative code domain power accuracy]

UE maximum output power reduction is an important issue for HSDPA. For release 5, table 3 taken from [7] shows the minimum requirements for the allowed reduction for different beta combinations when HS-DPCCH is fully or partially transmitted during a DPCCH timeslot.

Table 3 - UE Maximum Output Powers with HS-DPCCH

Ratio of $\beta_c$ to $\beta_d$ for all values of $\beta_{hs}$	Power Class 3		Power Class 4	
	Power (dBm)	Tol (dB)	Power (dBm)	Tol (dB)
$1/15 \leq \beta_c/\beta_d \leq 12/15$	+24	+1/-3	+21	+2/-2
$13/15 \leq \beta_c/\beta_d \leq 15/8$	+23	+2/-3	+20	+3/-2
$15/7 \leq \beta_c/\beta_d \leq 15/0$	+22	+3/-3	+19	+4/-2

These requirements have been modified for release 6, and a new metric to determine the allowed UE power reduction has been introduced.

### Cubic Metric

Practical experience gained in HSDPA has shown that PAR increase of a signal cannot be mapped 1-to-1 in dB to the required power back-off. With the new uplink channels for HSUPA, this issue has become even more crucial [13, 14]. Therefore, the cubic metric of a signal has been introduced in release 6 specifications as a more accurate measure for predicting the reduction in power capability of an amplifier [8]. It helps to reflect different physical channel configurations (number of codes, modulation, gain factor combinations, ...).

## HSDPA & HSUPA: Challenges for UE Power Amplifier Design

The Cubic Metric (CM) is based on the UE transmit channel configuration and defined as the power of a cubed signal under test with normalized rms level relative to the power of a cubed release 99 reference signal with normalized rms level:

$$CM = \text{CEIL} \{ [20 * \log_{10} ((v\_norm)^3 \text{ rms}) - 20 * \log_{10} ((v\_norm\_ref)^3 \text{ rms})] / k, 0.5 \}$$

Where

- CEIL{ x, 0.5 } means rounding upwards to closest 0.5dB, i.e.  $CM \in [0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5]$

- k is 1.85 for signals where all channelisation codes meet the following criteria  $C_{SF, N}$  where  $N < SF/2$

- k is 1.56 for signals where any channelisation codes meet the following criteria  $C_{SF, N}$  where  $N \geq SF/2$

- v\_norm is the normalized voltage waveform of the input signal

- v\_norm\_ref is the normalized voltage waveform of the reference signal (12.2 kbps AMR Speech) and  $20 * \log_{10} ((v\_norm\_ref)^3 \text{ rms}) = 1.52 \text{ dB}$

Background for the cubic metric is the fact that the main cause of ACLR is the third order nonlinearity of the power amplifier's gain characteristic.

Based on the cubic metric, the minimum requirements for the maximum output power are defined together for HSDPA and HSUPA. Table 4 shows the Maximum Power Reduction (MPR) in case HS-DPCCH or the HSUPA related channels E-DPDCH and E-DPCCH are fully or partially transmitted during a DPCCH timeslot [8].

Table 4 - Maximum Output Power with HS-DPCCH, E-DPDCH/E-DPCCH

UE transmit channel configuration	CM (dB)	MPR (dB)
For all combinations of; DPDCH, DPCCH, HS-DPCCH, E-DPDCH and E-DPCCH	$0 \leq CM \leq 3.5$	MAX (CM-1, 0)
Note 1: $CM = 1$ for $\beta_o/\beta_d = 12/15$ , $\beta_{hs}/\beta_c = 24/15$ . For all other combinations of DPDCH, DPCCH, HS-DPCCH, E-DPDCH and E-DPCCH the MPR is based on the relative CM difference.		

### Uplink Reference Measurement Channel for HSDPA

All transmitter tests in [12] are based on an uplink reference measurement channel for HS-DPCCH. It is assumed that a 12.2 kbps DPCCH/DPDCH is

## HSDPA & HSUPA: Challenges for UE Power Amplifier Design

set up in parallel to the HSDPA channels. Table 5 shows the 4 sub-tests which have to be performed for each of the above-mentioned transmitter test cases with HS-DPCCH.

Table 5 -  $\beta$  values for transmitter characteristics tests with HS-DPCCH

Sub-test	$\beta_c$	$\beta_d$	$\beta_d$ (SF)	$\beta_c/\beta_d$ (Note 1, Note 2)	$\beta_{HS}$	CM (dB) (Note 3)	MPR (dB) (Note 3)
1	1/15	15/15	64	1/15	2/15	0.0	0.0
2	12/15	15/15	64	12/15	24/15	1.0	0.0
3	15/15	8/15	64	15/8	30/15	1.5	0.5
4	15/15	1/15	64	15/1	30/15	1.5	0.5

Note 1:  $\Delta_{ACK}$ ,  $\Delta_{NACK}$  and  $\Delta_{CQI} = 30/15$  with  $\beta_{hs} = 30/15 * \beta_c$ .

Note 2: For the HS-DPCCH power mask requirement test in clause 5.7A, and the Error Vector Magnitude (EVM) with HS-DPCCH test,  $\Delta_{ACK}$  and  $\Delta_{NACK} = 30/15$  with  $\beta_{hs} = 30/15 * \beta_c$ , and  $\Delta_{CQI} = 24/15$  with  $\beta_{hs} = 24/15 * \beta_c$ .

Note 3: CM = 1 for  $\beta_c/\beta_d = 12/15$ ,  $\beta_{hs}/\beta_c = 24/15$ . For all other combinations of DPDCH, DPCCH and HS-DPCCH the MPR is based on the relative CM difference. This is applicable for only UEs that support HSDPA in release 6 and later releases.

### 3 HSUPA Uplink Design

#### E-DPDCH and E-DPCCH Physical Channel Structure

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 channel types:

- 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.

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).

## HSDPA & HSUPA: Challenges for UE Power Amplifier Design

The HSUPA related uplink channels are described in more detail in the following:

### E-DCH Dedicated Physical Data Channel: E-DPDCH

Figure 6 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. Table 6 shows the possible slot formats for E-DPDCH.

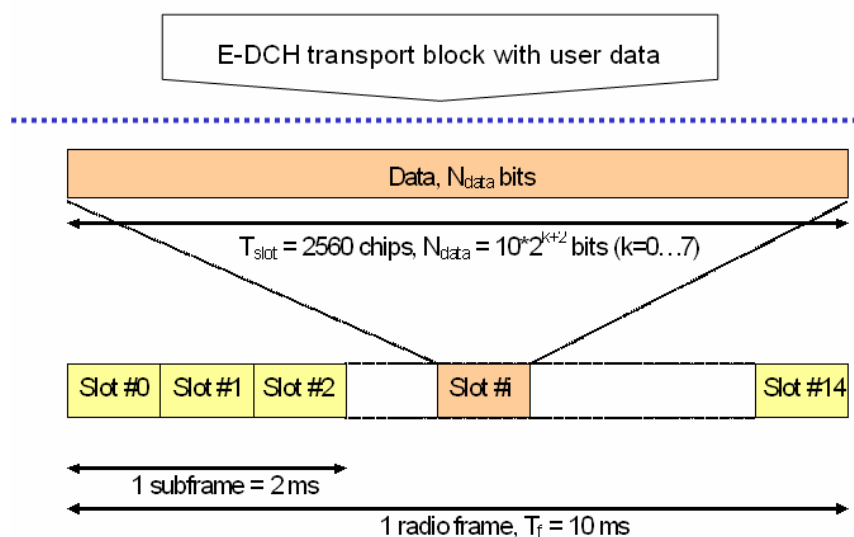


Figure 6 Structure of E-DPDCH

Table 6 E-DPDCH Slot Formats

Slot Format #i	Channel Bit Rate (kbps)	SF	Bits/ Frame	Bits/ Subframe	Bits/Slot $N_{\text{data}}$
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 4 E-DPDCHs with  $2 \cdot \text{SF}2$  and  $2 \cdot \text{SF}4$ . Also configurations of  $1 \cdot \text{SF} 4 \dots 256$ ,  $2 \cdot \text{SF}2$ , or  $2 \cdot \text{SF}4$  are possible.

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).

### Determination of SF and number of E-DPDCHs

It is specified in [4] how the UE determines the required number of E-DPDCHs and the required spreading factor for the transmission of a certain transport block size. This can be done in 3 steps.

The number of available air interface bits per TTI of one E-DPDCH for all possible spreading factors is denoted by  $N_{256}$ ,  $N_{128}$ ,  $N_{64}$ ,  $N_{32}$ ,  $N_{16}$ ,  $N_8$ ,  $N_4$  and  $N_2$ , where the index refers to the spreading factor.

$N_{e,data}$  are the possible number of bits available on all E-DPDCHs in this TTI  $\{N_{256}, N_{128}, N_{64}, N_{32}, N_{16}, N_8, N_4, 2 \times N_4, 2 \times N_2, 2 \times N_2 + 2 \times N_4\}$ .

The total number of bits in a TTI before rate matching with transport format  $j$  is  $N_{e,j}$

The maximum amount of puncturing that can be applied is:

- $1 - PL_{non-max}$  if the number of code channels is less than the maximum allowed by the UE capability and restrictions imposed by UTRAN ( $PL_{non-max}$  is signaled by higher layers).

- $1 - PL_{max}$  if the number of code channels equals to the maximum allowed by the UE capability and restrictions imposed by UTRAN ( $PL_{max} = 0.33$  for 4 E-DPDCHs, else  $PL_{max} = 0.44$ ).

1. Select the min. possible  $N_{e,data}$  such that  $N_{e,data} - N_{e,j}$  is non negative.

2. If this selection requires more than one E-DPDCH select the minimum  $N_{e,data}$  which complies to the condition that  $N_{e,data} - PL_{non-max} \times N_{e,j}$  is non negative.

3. If there is no  $N_{e,data}$  that complies select a maximum  $N_{e,data}$  that complies to the condition that  $N_{e,data,j} - PL_{max} \times N_{e,j}$  is not negative.

### E-DCH Dedicated Physical Control Channel: E-DPCCH

Figure 7 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:



## HSDPA & HSUPA: Challenges for UE Power Amplifier Design

- 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)

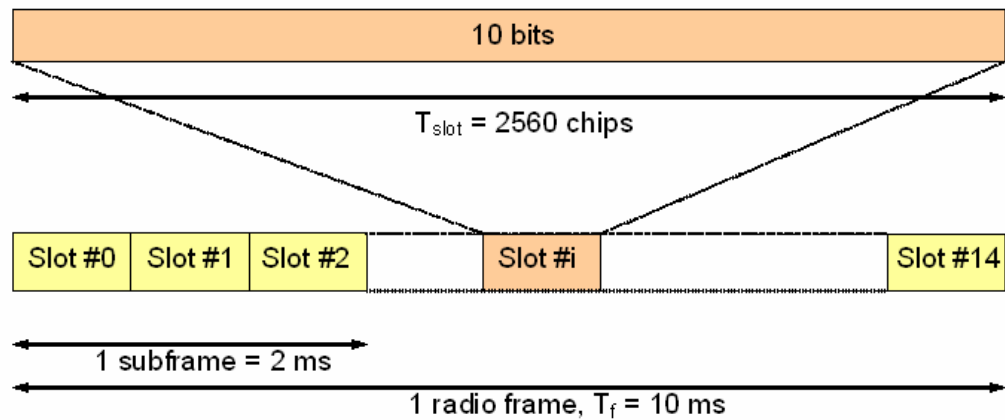


Figure 7 Structure of E-DPCCH

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 8.

## HSDPA & HSUPA: Challenges for UE Power Amplifier Design

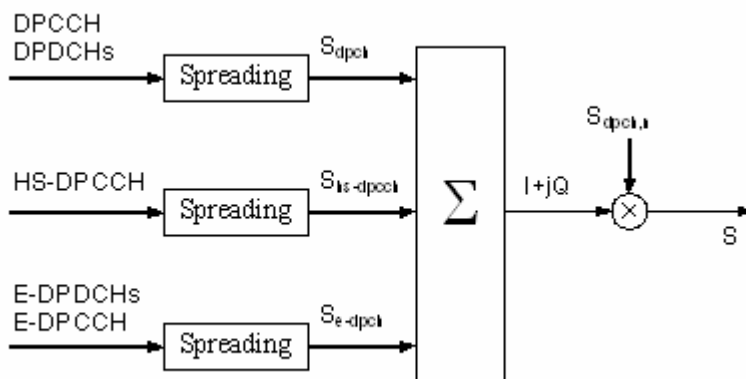


Figure 8 Uplink Spreading Operation for Dedicated Channels (DPCCH/DPDCHs), HSDPA (HS-DPCCH), and HSUPA (E-DPDCHs, E-DPCCH)

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 ( $N_{\max\text{-dpdch}}$ ) and on whether HSDPA is configured or not, see table 7.

Table 7 Mapping of E-DPDCHs onto I/Q domain

$N_{\max\text{-dpdch}}$	HS-DSCH configured	E-DPDCH <sub>k</sub>	$iq_{e,d^k}$
0	No/Yes	E-DPDCH <sub>1</sub>	1
		E-DPDCH <sub>2</sub>	j
		E-DPDCH <sub>3</sub>	1
		E-DPDCH <sub>4</sub>	j
1	No	E-DPDCH <sub>1</sub>	j
		E-DPDCH <sub>2</sub>	1
1	Yes	E-DPDCH <sub>1</sub>	1
		E-DPDCH <sub>2</sub>	j

Note that the possible uplink channel combinations are limited. Table 8 shows the allowed configurations.

Table 8 Uplink Channel Configurations

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 9 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

## HSDPA & HSUPA: Challenges for UE Power Amplifier Design

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.

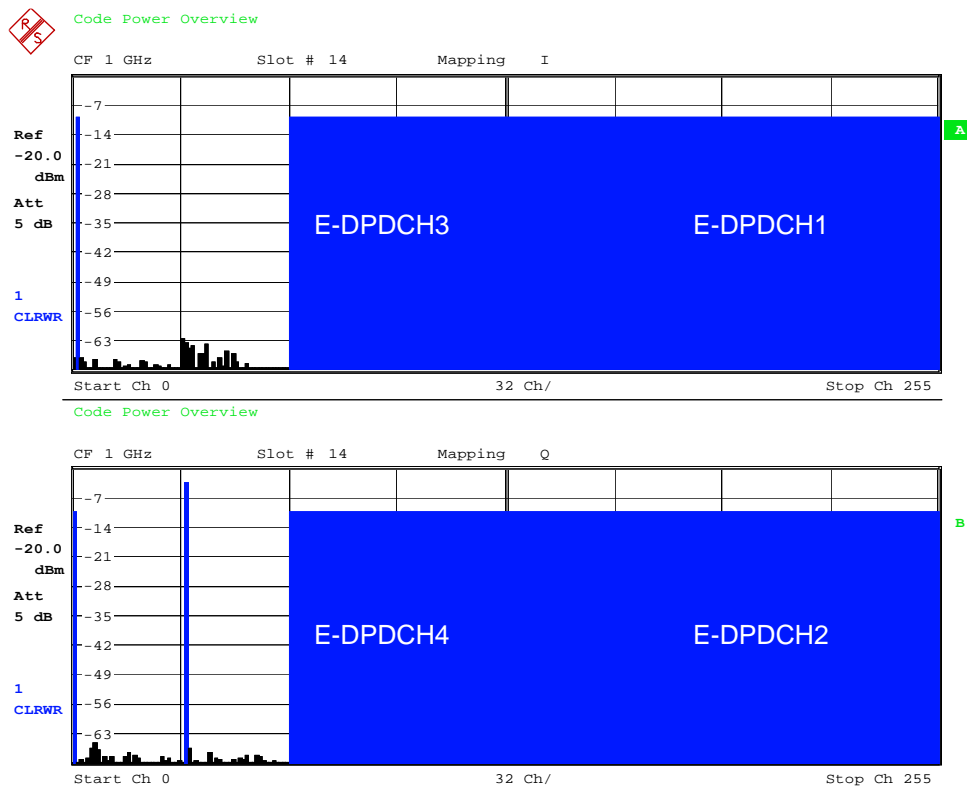


Figure 9 Code domain display of HSUPA uplink signal, measured with FSQ

In figure 9, E-DPDCH1 and E-DPDCH2 use the same channelization code (1<sup>st</sup> code of SF2), and E-DPDCH3 and E-DPDCH4 use the same channelization code (1<sup>st</sup> code of SF4). HS-DPCCH uses code 33 of SF256 in this configuration.

Figure 10 illustrates the mapping of the E-DPDCHs for configuration #3.

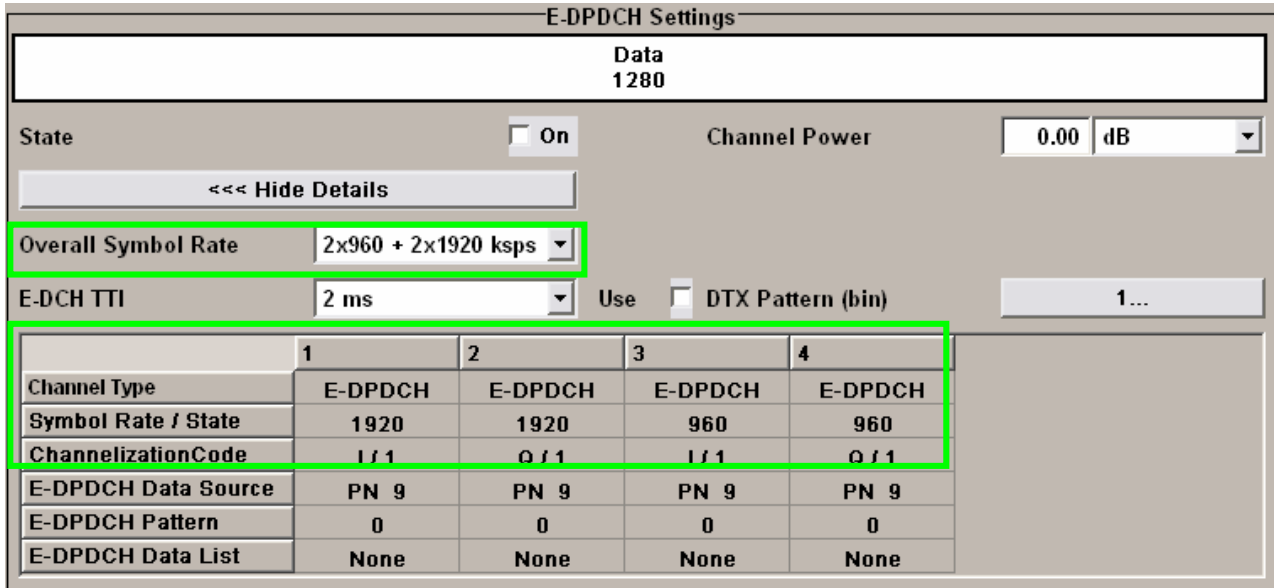


Figure 10 Configuration of 4 E-DPDCHs with SMx Signal Generator

**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 11. They are called  $\beta_{ec}$  for E-DPCCH and  $\beta_{ed,k}$  for the E-DPDCH(s).

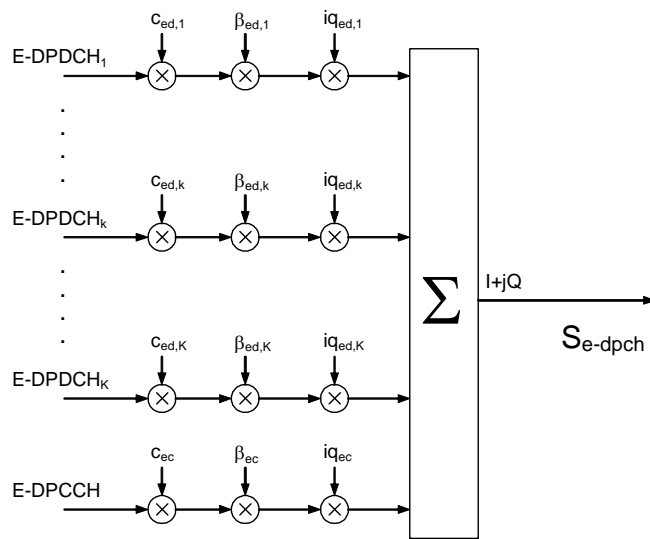


Figure 11 Uplink Spreading and Gain Factor Usage for HSUPA

## HSDPA & HSUPA: Challenges for UE Power Amplifier Design

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  $\beta_{ec}$ , which is given by:

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

where  $\beta_c$  is the gain factor of the DPCCH.  $\beta_c$  is either signaled by higher layers to the UE, or computed according to [6]. The ratio  $A_{ec}$  is derived from the parameter  $\Delta E-DPCCH$  signaled by higher layers, e.g. at call setup. Table 9 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 9 – E-DPCCH power relative to DPCCH

Signaling values for $\Delta E-DPCCH$	Quantized amplitude ratios $A_{ec} = \beta_{ec} / \beta_c$	E-DPCCH power to be set in relation to DPCCH
8	30/15	6.02
7	24/15	4.08
6	19/15	2.05
5	15/15	0.0
4	12/15	-1.94
3	9/15	-4.44
2	8/15	-5.46
1	6/15	-7.96
0	5/15	-9.54

During compressed frames, the E-DPCCH gain factor  $\beta_{ec}$  needs to be scaled according to [6].

### 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 11. 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-DPDCH 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.

## HSDPA & HSUPA: Challenges for UE Power Amplifier Design

*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 [6].

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  $\beta_c$  is the gain factor of the DPCCH. The ratio  $A_{ed}$  is derived from the parameter  $\Delta E$ -DPDCH signaled by higher layers for the selected reference E-TFC. Table 10 shows the meaning of the signaled values for  $\Delta E$ -DPDCH.

*Background:*

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

Table 10 Quantization for  $\Delta E$ -DPDCH

Signalled values for $\Delta E$ -DPDCH	Quantized amplitude ratios $A_{ed} = \beta_{ed}/\beta_e$
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.

$\Delta_{harq}$  is the HARQ offset for the specific data flow to be transmitted (so-called "MAC-d flow") as signaled by higher layers (see table 11).

Table 11 HARQ Offset  $\Delta_{harq}$

Signalling values for $\Delta_{harq}$	Power offset values $\Delta_{harq}$ [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 12 to obtain the ratio  $\beta_{ed,k} / \beta_c$ .



Table 12 Quantization for  $\beta_{ed,k}/\beta_c$

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 according to [6].

### UE Transmitter Tests for HSUPA

[12] currently contains the following transmitter tests for HSUPA UEs:

- Test Case 5.2B: Maximum Output Power with HS-DPCCH and E-DCH
- Test Case 5.9B: Spectrum Emission Mask with E-DCH
- Test Case 5.10B: Adjacent Channel Leakage Power Ratio (ACLR) with E-DCH

Also for HSUPA, the cubic metric is used to determine the maximum power reduction for different signal characteristics. Thus, table 4 is also valid for HSUPA.

### Uplink Reference Measurement Channel for E-DCH Tests

The reference measurement channel for E-DCH tests describes L1 and L2 parameters to use for the test cases [12]. For transmitter tests, table 13 shows the required beta combinations.

## HSDPA & HSUPA: Challenges for UE Power Amplifier Design

Table 13  $\beta$  values for UE transmitter tests with HS-DPCCH/E-DCH

Sub - test	$\beta_c$	$\beta_d$	$\beta_d$ (SF)	$\beta_c/\beta_d$	$\beta_{HS}$ (Note 1)	$\beta_{ec}$	$\beta_{ed}$	$\beta_{ed}$ (SF)	$\beta_{ed}$ (Code s)	CM (dB) (Note 2)	MPR (dB) (Note 2)
1	8/15	15/15	64	8/15	16/15	16/15	448/75	4	1	1.0	0.0
2	6/15	15/15	64	6/15	12/15	12/15	94/75	4	1	3.0	2.0
3	15/15	5/15	64	15/5	30/15	30/15	$\beta_{ed1}$ : 47/15 $\beta_{ed2}$ : 47/15	4 4	2	2.0	1.0
4	1/15	15/15	64	1/15	2/15	2/15	56/75	4	1	3.0	2.0
5	12/15	15/15	64	12/15	24/15	24/15	224/25	4	1	1.0	0.0

Note 1:  $\Delta_{ACK}$ ,  $\Delta_{NACK}$  and  $\Delta_{CQI} = 30/15$  with  $\beta_{hs} = 30/15 * \beta_c$ .

Note 2: CM = 1 for  $\beta_c/\beta_d = 12/15$ ,  $\beta_{hs}/\beta_c = 24/15$ . For all other combinations of DPDCH, DPCCH, HS-DPCCH, E-DPDCH and E-DPCCH the MPR is based on the relative CM difference.

## 4 Basic Test Setups with R&S Instruments

In this chapter, it is explained how to create and analyze HS-DPCCH, E-DPCCH and E-DPDCH signals for UE power amplifier testing with R&S instruments.

### Generation of HS-DPCCH, E-DPCCH and E-DPDCH

For generating these signals, signal generators **SMU200A**, **SMJ100A** or **SMATE200A** are available. Software option SMx-K43 (3GPP FDD enhanced MS/BS tests, incl. HSDPA, requires SMx-K42) provides HSDPA functionality on these signal generators. Software option SMx-K45 provides HSUPA functionality (3GPP FDD HSUPA, requires SMx-K42).

Alternatively, **WinIQSIM2** simulation software provides the possibility to generate HS-DPCCH and E-DCH signals. WinIQSIM2 is running on a PC and can generate waveforms for digitally modulated signals which can be output by the Arbitrary Waveform Generator **AFQ100A** as well as the integrated solutions in the vector signal generators SMU200A and the SMJ100A.

In the following, SMU200A signal generator is exemplarily used to demonstrate the test setup for the signal generation.

With the SMU200A, settings for digital modulation can be accessed via the baseband function block in the block diagram of the user interface. Figure

## HSDPA & HSUPA: Challenges for UE Power Amplifier Design

12 shows the 3GPP FDD menu within the baseband function block. An uplink signal is created. By double-clicking on the selected User Equipment (UE1 in this example), it is possible to access more detailed settings of the generated signal including DPCCH, DPDCH, HS-DPCCH, E-DPCCH and E-DPDCH parameters

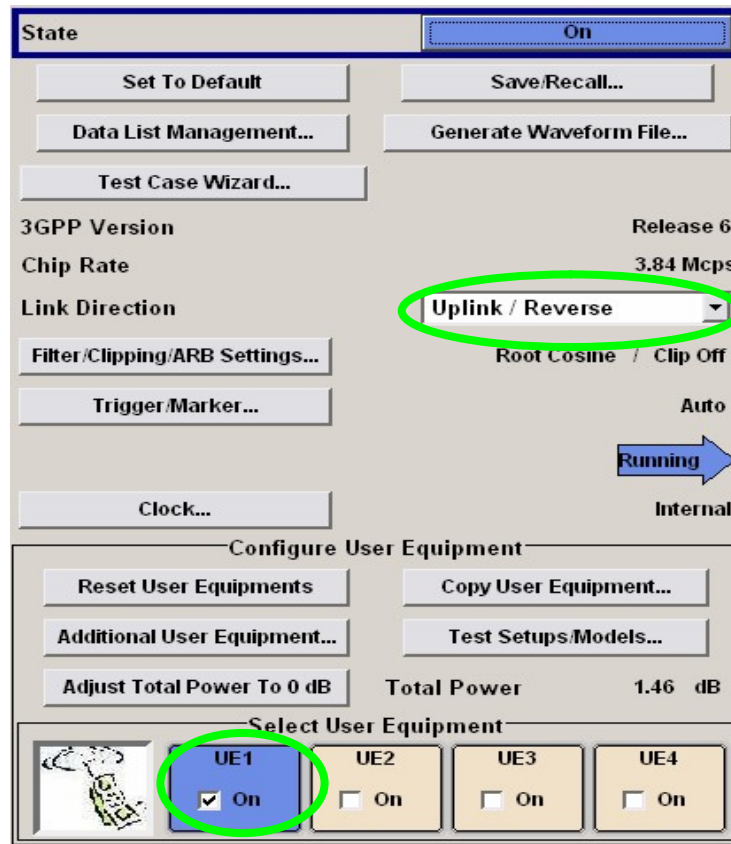


Figure 12 – Uplink signal generation with SMU200A

Figure 13 shows the possible **HS-DPCCH** settings with SMU200A. The sub-frame structure of the HS-DPCCH is graphically illustrated. Power, Start Delay, Inter TTI Distance, CQI pattern, and ACK/NACK pattern can be selected. The parameter Start Delay is corresponding to the parameter  $m$  in figure 5, and is therefore determining the position of the HS-DPCCH compared to the uplink DPCH frame boundary. Power offsets for ACK and NACK fields within HS-DPCCH can be set independently in relation to the HS-DPCCH power. CQI power is then equal to HS-DPCCH power.

## HSDPA & HSUPA: Challenges for UE Power Amplifier Design

Figure 13 – HS-DPCCH Settings in SMU200A menu

Figure 14 shows the possible **E-DPCCH** settings with SMU200A. The sub-frame structure of the E-DPCCH is graphically illustrated. Power, Retransmission Sequence Number, E-TFCI Information, E-DCH TTI, Happy Bit and a DTX Pattern can be selected. Selection of HSUPA Fixed Reference channels required for BS testing according to 3GPP TS 25.141 [16] can be obtained by the HSUPA FRC button.

Figure 14 – E-DPCCH Settings in SMU200A menu

Figure 15 shows the possible **E-DPDCH** settings with SMU200A. The sub-frame structure of the E-DPDCH is graphically illustrated. Channel Power, Symbol Rate, E-DCH TTI, DTX Pattern and adjustments on each of the four possible data channels can be selected.

**E-DPDCH Settings**

---

Data  
1280

State  On Channel Power -10.00 dB

<<< Hide Details

Overall Symbol Rate 2 x 960 kbps

E-DCH TTI 10 ms Use  DTX Pattern (bin) 1...

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

Figure 15 – E-DPDCH Settings in SMU200A menu

### Setting Gain Factors for HS-DPCCH, E-DPCCH, and E-DPDCH

The power of DPCCH, DPDCH, and HS-DPCCH, E-DPCCH and E-DPDCH is set in dB. The power value is set in relation to the channel with the highest power. Only if **Adjust Total Power to 0 dB** is pressed in the main menu (see figure 12), the power of the individual code channels is set so that the sum power of all active channels is 0 dB. In this case, the set power differences of all channels remain the same but the total power is normalized to 0 dB.

In the following, the setting of **HS-DPCCH** gain factors on SMU200A is explained.

In order to manually adjust gain factors for DPCCH and DPDCH, table 14 shows the power values to be set with the SMU200A or with WinIQSIM2 in order to reflect signaling values for  $\beta_c$  and  $\beta_d$ . Note that either  $\beta_c$  or  $\beta_d$  must have the signaling value 15, i.e. either DPCCH or DPDCH has to be set with level 0 dB and the level of the respective other channel is then set in relation to 0 dB according to table 14.

## HSDPA & HSUPA: Challenges for UE Power Amplifier Design

Table 14 – Power values to be set on SMU200A for  $\beta_c$  and  $\beta_d$  values

Signaling values for $\beta_c$ and $\beta_d$	Quantized amplitude ratios for $\beta_c$ and $\beta_d$	Power to be set for R&S Vector Signal Generator / dB
15	1.0	0.0
14	14/15	-0.60
13	13/15	-1.24
12	12/15	-1.94
11	11/15	-2.69
10	10/15	-3.52
9	9/15	-4.44
8	8/15	-5.46
7	7/15	-6.62
6	6/15	-7.96
5	5/15	-9.54
4	4/15	-11.48
3	3/15	-13.99
2	2/15	-17.52
1	1/15	-23.52
0	Switch off	Switch channel off or -80dB

In case of additional HS-DPCCH, its levels are set in relation to the DPCCH according to table 15.

Table 15 – HS-DPCCH power relative to DPCCH

Signaling values for $\Delta_{ACK}$ , $\Delta_{NACK}$ and $\Delta_{CQI}$	Quantized amplitude ratios for $10^{\left(\frac{\Delta_{HS-DPCCH}}{20}\right)}$	HS-DPCCH power to be set in relation to DPCCH
8	30/15	6.02
7	24/15	4.08
6	19/15	2.05
5	15/15	0.0
4	12/15	-1.94
3	9/15	-4.44
2	8/15	-5.46
1	6/15	-7.96
0	5/15	-9.54

## HSDPA & HSUPA: Challenges for UE Power Amplifier Design

It needs to be considered that in the SMU200A and in WinIQSIM2, the level of the channel with the highest power has to be set to 0 dB. The power of the other channels is then set in relation to 0 dB. This step is simplified with the demo software explained below in this chapter.

Setting of gain factors for **E-DPCCH** works in a similar way. Table 16 shows the required power values depending on  $\beta_{ec}$ .

Table 16 – E-DPCCH power relative to DPCCH

Signaling values for $\Delta_{E-DPCCH}$	Quantized amplitude ratios $A_{ec} = \beta_{ec} / \beta_c$	E-DPCCH power to be set in relation to DPCCH
8	30/15	6.02
7	24/15	4.08
6	19/15	2.05
5	15/15	0.0
4	12/15	-1.94
3	9/15	-4.44
2	8/15	-5.46
1	6/15	-7.96
0	5/15	-9.54

For E-DPDCH, the principle of setting gain factors is the same as for the other uplink channels. However, more parameters are influencing the exact gain factor selection, e.g. transport block size, HARQ profile. Therefore, table 17 exemplarily shows the power values to set on SMU200A or WinIQSIM2 in order to reflect the subtests of [12] required for UE transmitter testing, see table 13 as mentioned above.

Table 17 Power values for uplink channels to be used for transmitter tests in 3GPP TS 34.121

Subtest	DPCCH $\beta_c$	DPDCH $\beta_d$	HS-DPCCH $\beta_{HS}$	E-DPCCH $\beta_{ec}$	E-DPDCH $\beta_{ed}$
1	-20,98dB	-15,52dB	-14,96dB	-14,96dB	0dB
2	-9,92dB	-1,96dB	-3,9dB	-3,9dB	0dB
3	-9,92dB	-19,46dB	-3,9dB	-3,9dB	0dB/0dB
4	-23,52dB	0dB	-17,5 dB	-17,5 dB	-2,54dB
5	-20,98 dB	-19,04dB	-14,96dB	-14,96dB	0dB

Figures 16-20 show the resulting code domain views for these subtests.

# HSDPA & HSUPA: Challenges for UE Power Amplifier Design

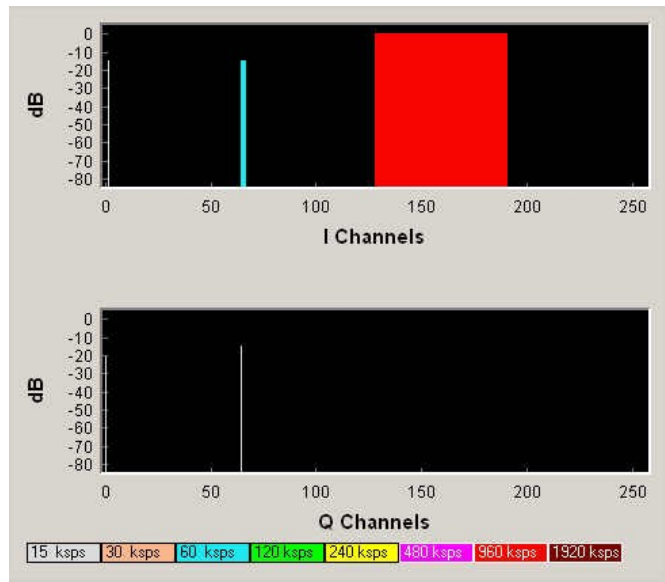


Figure 16 Code Domain for subtest 1

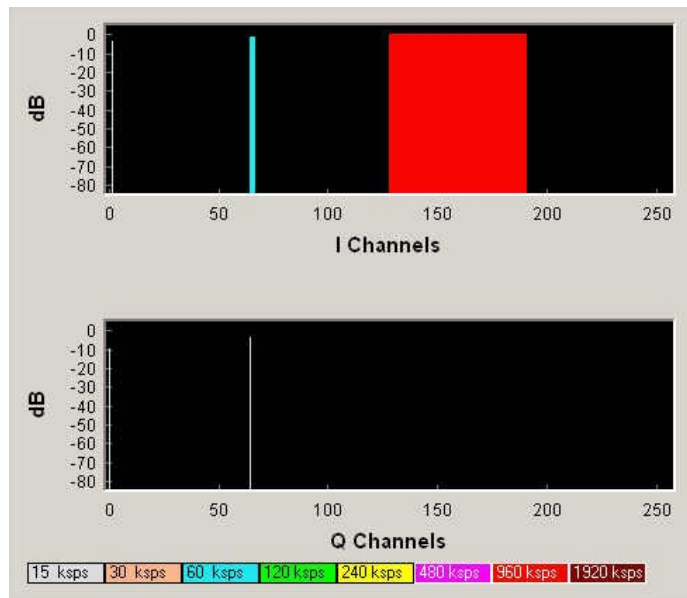


Figure 17 Code Domain for subtest 2



## HSDPA & HSUPA: Challenges for UE Power Amplifier Design

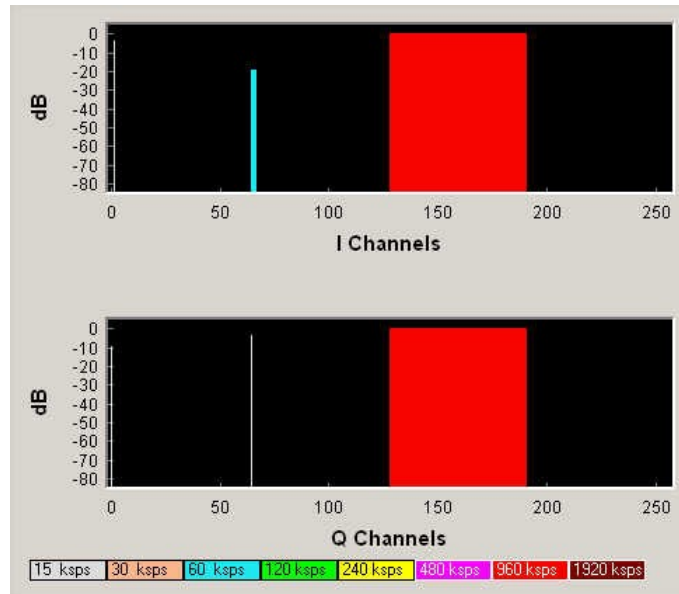


Figure 18 Code Domain for subtest 3

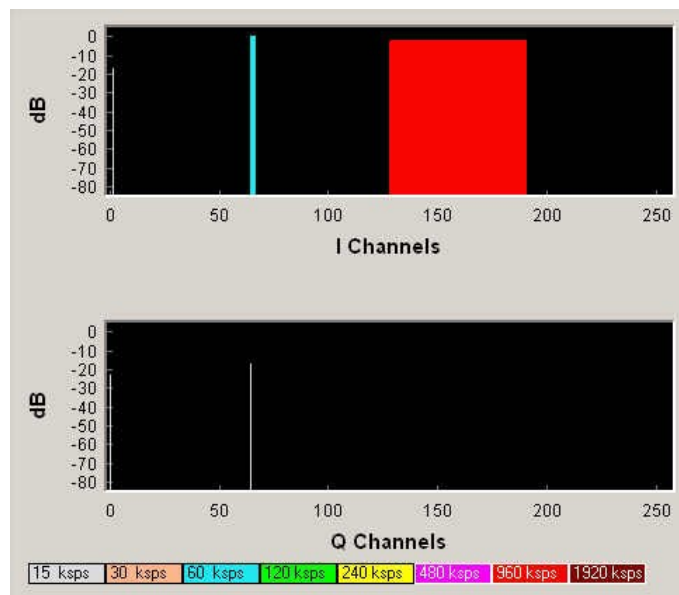


Figure 19 Code Domain for subtest 4

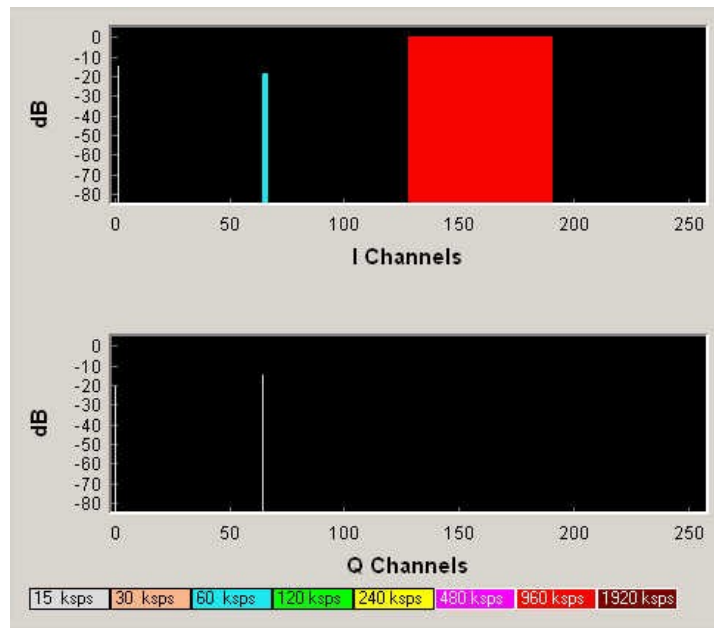


Figure 20 Code Domain for subtest 5

### Analysis of HS-DPCCH, E-DPCCH, E-DPDCH with R&S Instruments

For analyzing the RF characteristics of an HS-DPCCH or E-DCH signal, spectrum analyzers **FSU** and **FSP** as well as the signal analyzer **FSQ** can be used. Software options FS-K72 (*3GPP-FDD BTS transmitter test for FSMR, FSP, FSU, FSQ*), FS-K73 (*Application firmware 3GPP-FDD UE transmitter test for FSMR, FSP, FSU, FSQ*) and FS-K74 (*3GPP HSDPA base station test application firmware for FSMR, FSU, FSP, FSQ*) provide HSDPA and HSUPA functionality.

Also the **CMU200** Universal Radio Communication Tester provides a variety of uplink analysis and measurement functions for HSDPA and HSUPA. Software Options CMU-K64 (*Software option for CMU200: HSDPA*) and CMU-K60 (*Software option for CMU200: HSDPA 10 Mbps ext.*) enable HSDPA functionality, and software option CMU-K56 (*Software option for CMU200: HSUPA 5.7 Mbps*) enables HSUPA functionality. CMU200 functionality is shown at the end of this chapter.

In the following, FSQ signal analyzer is exemplarily used to demonstrate the test setup for uplink analysis.

For power amplifier design, particularly ACLR, crest factor, EVM and spectrum measurements are of interest. These measurements can be performed conveniently and with highest accuracy with the FSQ.

## HSDPA & HSUPA: Challenges for UE Power Amplifier Design

For accessing the ACLR measurement, press the key MEAS, and then the ACLR softkey. The instrument measures the channel power and the relative power of adjacent channels and of the next channels. Figure 21 shows an example.

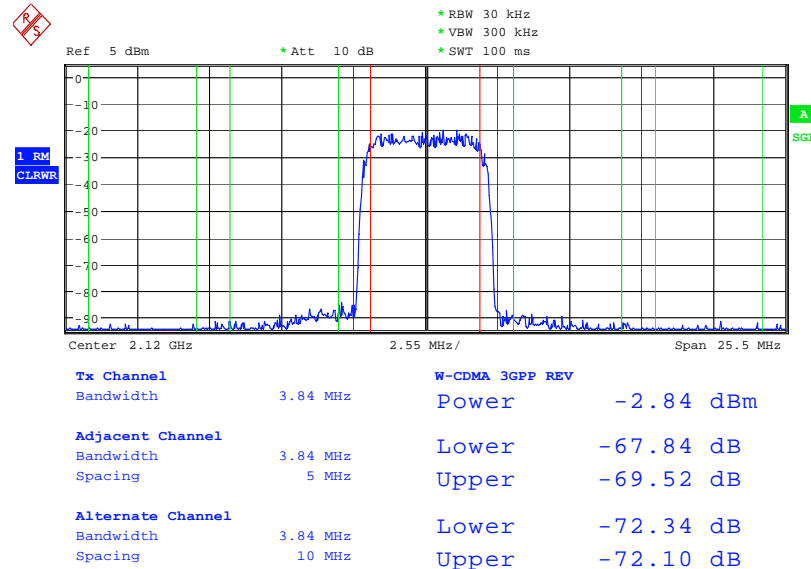


Figure 21 - ACLR measurement with FSQ

In the following you find a short explanation where you can find more relevant measurements within the FSQ menu:

- Crest factor: via key MEAS, softkey STATISTICS
- Spectrum emission mask: via key MEAS, softkey SPECTRUM EM MASK
- Composite EVM measurement: via hotkey RESULTS

As further examples, figures 22 and 23 show crest factor measurements on FSQ with different beta factor combinations. Figure 22 shows the CCDF of an example reference signal without HS-DPCCH and with gain factors  $\beta_c/\beta_d = 8/15$ . The signal contains 1 DPDCH (channelization code 64 of SF 64). The crest factor of this signal is 3.56 dB. The measurement has been made with the FSQ.

## HSDPA & HSUPA: Challenges for UE Power Amplifier Design

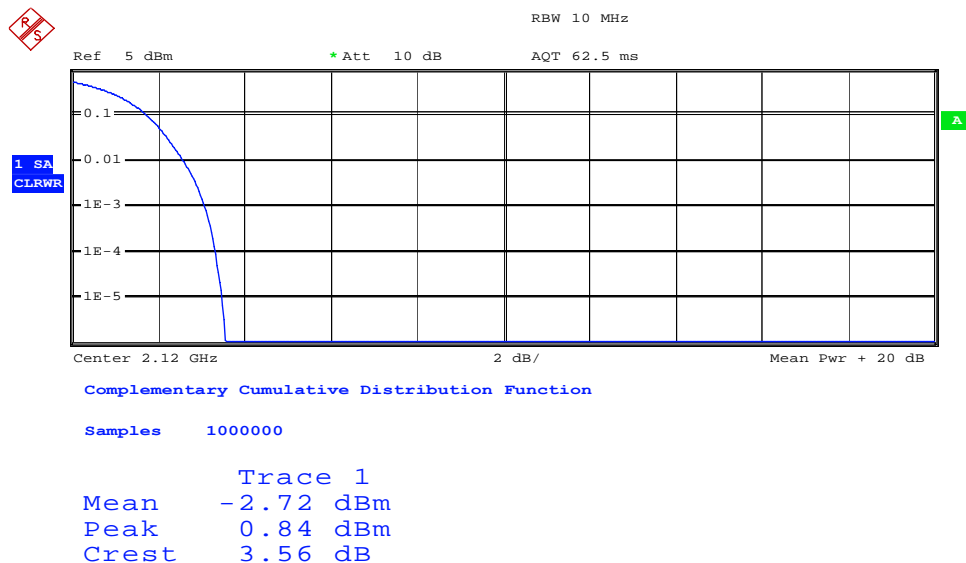


Figure 22 - Crest factor for  $\beta_c/\beta_d = 8/15$ , no HS-DPCCH

For comparison, an HS-DPCCH is added to this signal, and  $\beta_c/\beta_d/\beta_{hs} = 15/8/15$  is selected. HS-DPCCH is assumed to be time aligned to uplink DPCCH (parameter start delay = 0), and Inter TTI distance of 3 is selected.

Figure 23 shows the resulting CCDF measured with FSQ. The crest factor has increased to 6.81 dB.

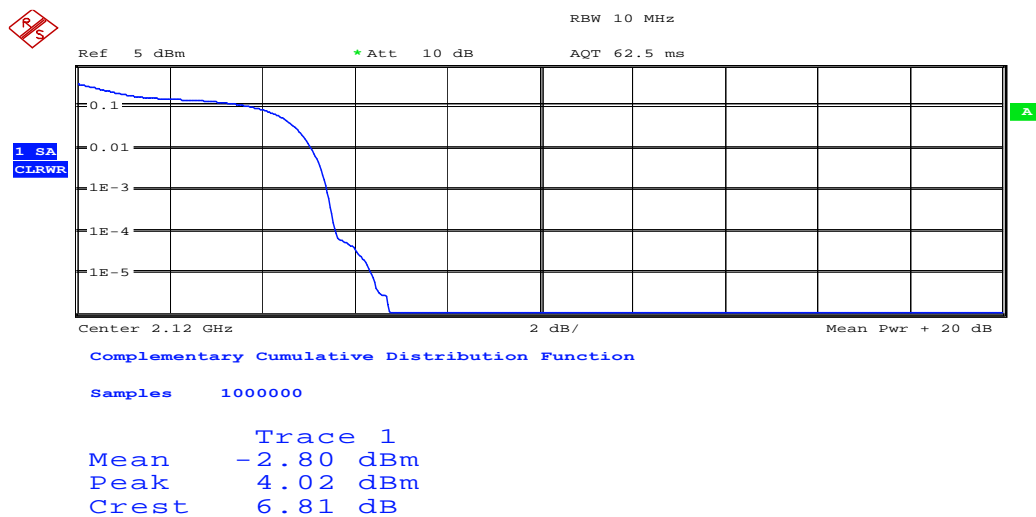


Figure 23 - Crest factor for  $\beta_c/\beta_d/\beta_{hs} = 15/8/15$

Of course, the same measurement types are available for an HSUPA signal.

The **Radio Communication Tester CMU200** offers HS-DPCCH analysis functionality in signaling and non-signaling mode. In signaling mode,

## HSDPA & HSUPA: Challenges for UE Power Amplifier Design

various parameters relevant for HS-DPCCH can be adjusted which are then signaled by higher layers (RRC – Radio Resource Control) to the UE. The UE accordingly configures its HS-DPCCH transmission. Figure 24 shows the menu where gain factors  $\beta_c$ ,  $\beta_d$  and power offsets  $\Delta_{ACK}$ ,  $\Delta_{NACK}$  and  $\Delta_{CQI}$  can be set according to the signaling values as given in tables 1 and 2 of this application note.

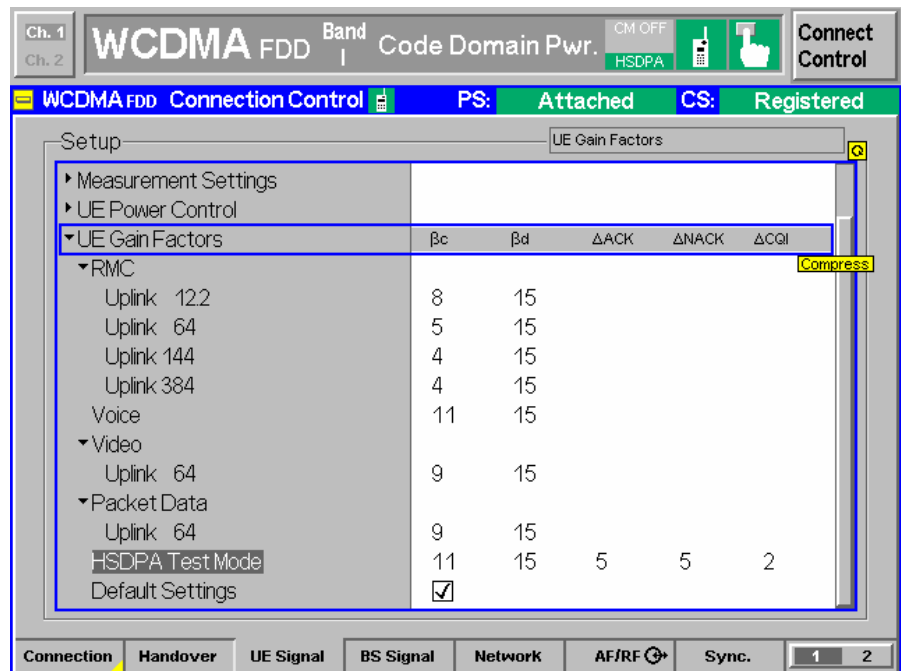


Figure 24 – Setting of gain factors in CMU200

As explained in chapter 2, the downlink DPCH frame offset ( $T_{dpch\_offset}$  in figure 5) directly influences the timing of the HS-DPCCH in relation to the uplink DPCH frame boundary. The CMU200 allows to adjust the downlink DPCH frame offset in multiples of 256 chips which will be signaled by RRC to the UE. Figure 25 shows the menu for setting this parameter.

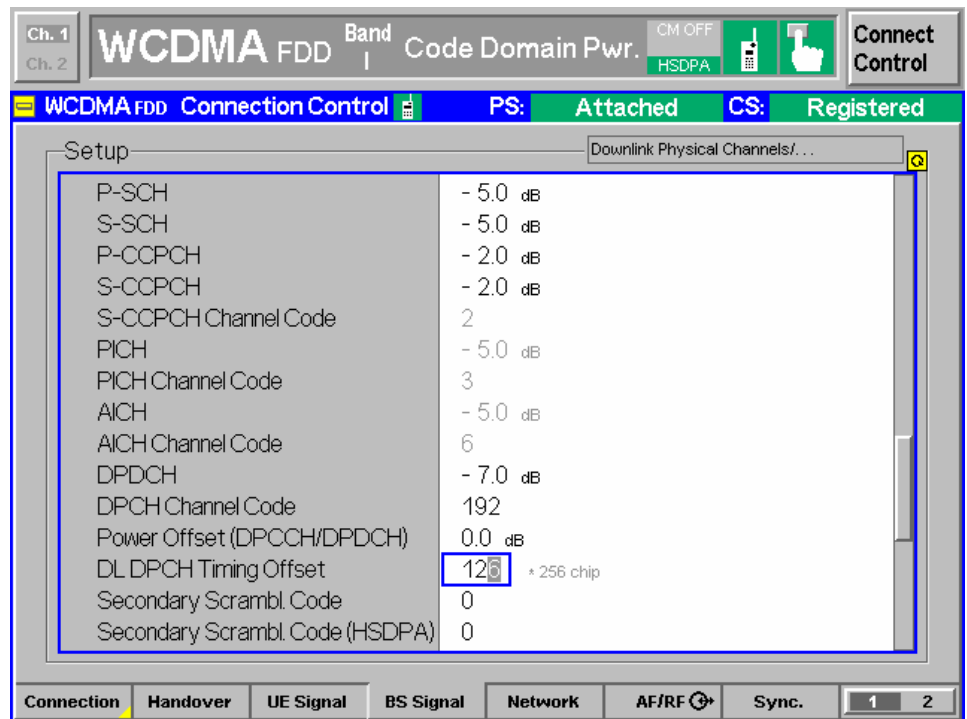


Figure 25 – Setting of Downlink DPCH frame offset in CMU200

Note that a downlink DPCH frame offset of 0 chips results in an HS-DPCCH timing of 1 symbol delay (corresponding to 1/10 of a time slot) compared to the uplink DPCH slot boundary. A downlink DPCH frame offset of 1, 11, 21, ... \* 256 chips will result in a slot alignment of uplink DPCH and HS-DPCCH.

Different measurement possibilities exist for the HS-DPCCH, both in signaling and non-signaling mode. An internal trigger can be generated upon HS-DPCCH reception which can be used for triggering power, spectrum, and modulation measurements. Individual trigger offsets can be adjusted. Figure 26 shows a modified code domain display which allows to estimate power levels of DPCCH, DPDCH and HS-DPCCH, as well as a representation of the power of the 10 symbols contained in one HS-DPCCH time slot. The measurement is done over one uplink DPCH time slot.

# HSDPA & HSUPA: Challenges for UE Power Amplifier Design

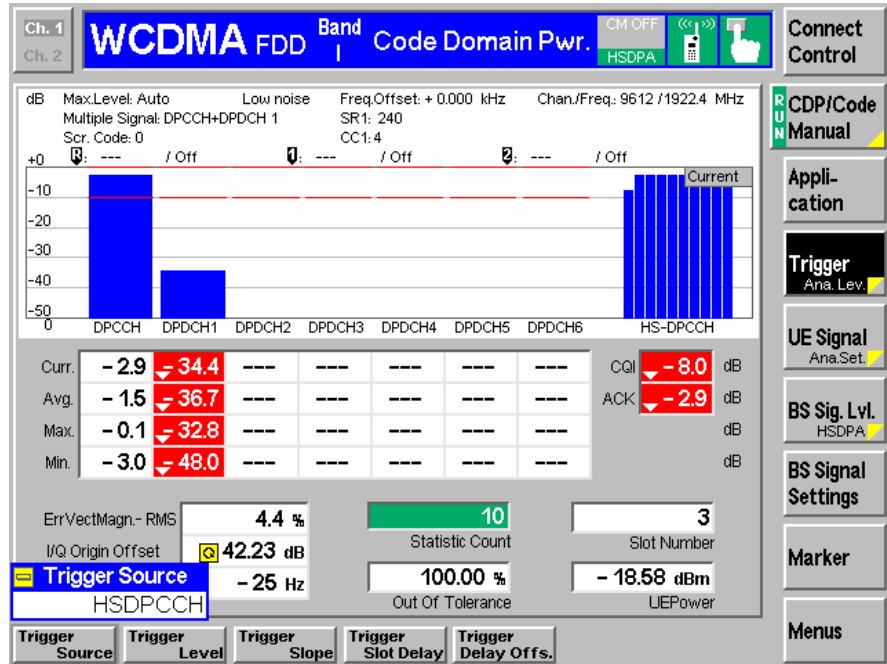


Figure 26 – Analysis of HS-DPCCH power (per symbol over a measurement interval of 1 UL DPCH time slot); HS-DPCCH with ACK/NACK and CQI

In the measurement in figure 26, HS-DPCCH is not slot aligned with uplink DPCH. The downlink DPCH frame offset is set to 0, so the HS-DPCCH time slot starts one symbol later than the uplink DPCH slot. The HS-DPCCH sub-frame in this example contains ACK/NACK and CQI values. Since different power values for  $\Delta$ ACK,  $\Delta$ NACK and  $\Delta$ CQI have been set, one can see a power step within the measured slot. Figure 27 illustrates the measurement principle

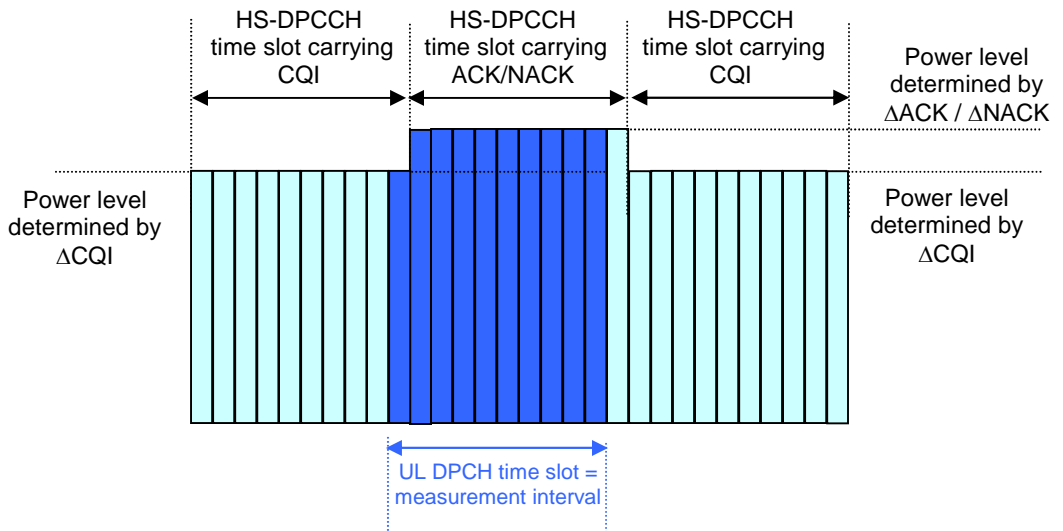


Figure 27 – HS-DPCCH slot timing not aligned with uplink DPCH slot timing

## HSDPA & HSUPA: Challenges for UE Power Amplifier Design

As another example, in figure 28, an HS-DPCCH sub-frame without an ACK/NACK field (DTX) has been measured.

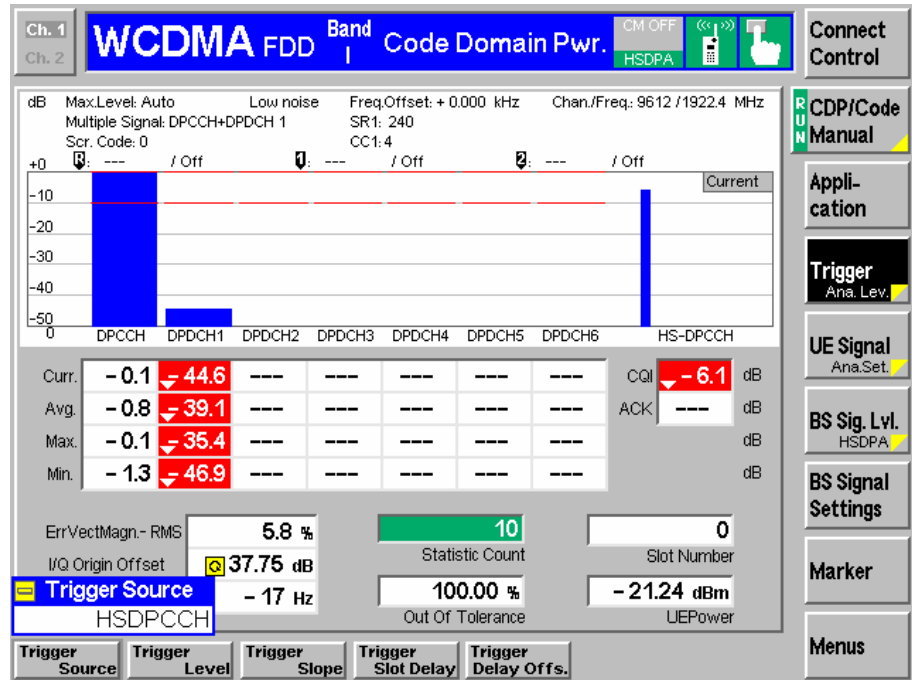


Figure 28 – Analysis of HS-DPCCH power (per symbol over a measurement interval of 1 UL DPCH time slot), no ACK/NACK field

The timing of the HS-DPCCH and the measurement interval is still as in figure 26, but this time, the ACK/NACK field of HS-DPCCH is blanked.

Figure 29 shows an EVM measurement of a signal containing HS-DPCCH.

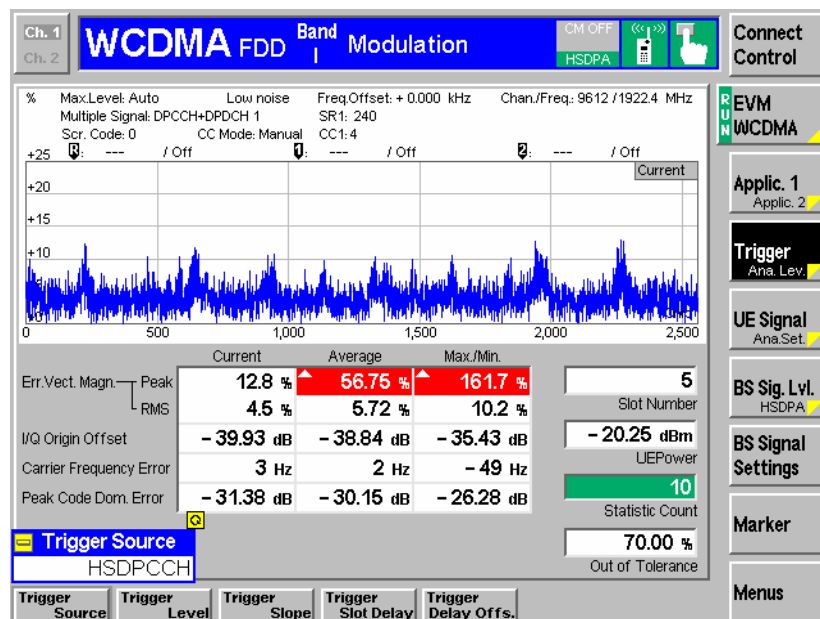


Figure 29 – EVM Measurement of a signal containing HS-DPCCH



## HSDPA & HSUPA: Challenges for UE Power Amplifier Design

Figure 30 shows the code domain analysis on CMU200 for a signal containing E-DPDCHs and E-DPCCH, and figure 31 shows the modified code domain view indicating the measured power values of all uplink channels separately.

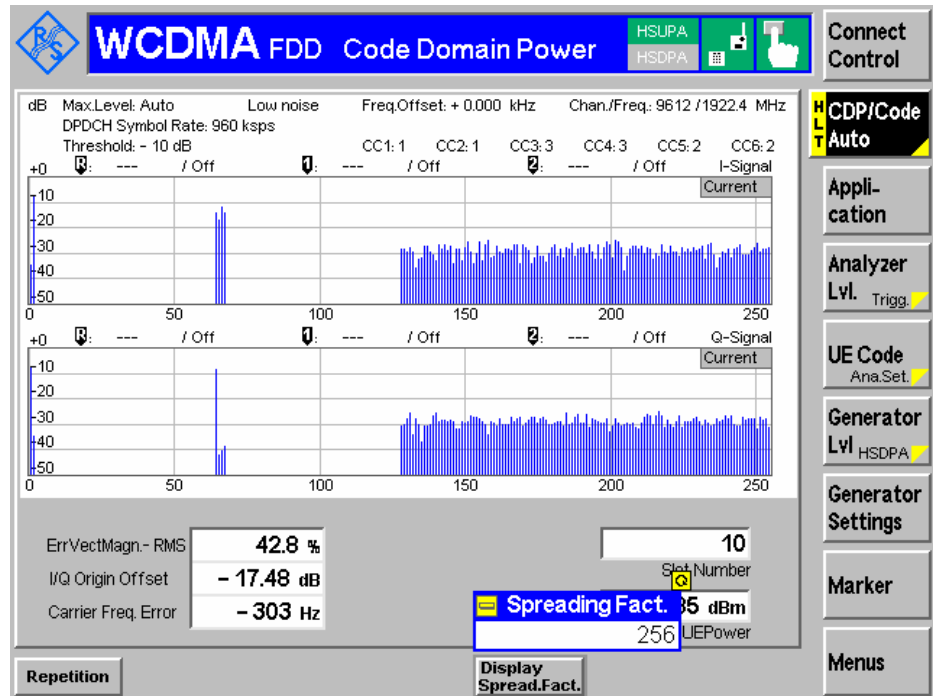


Figure 30 – Code domain view of HSUPA signal on CMU200

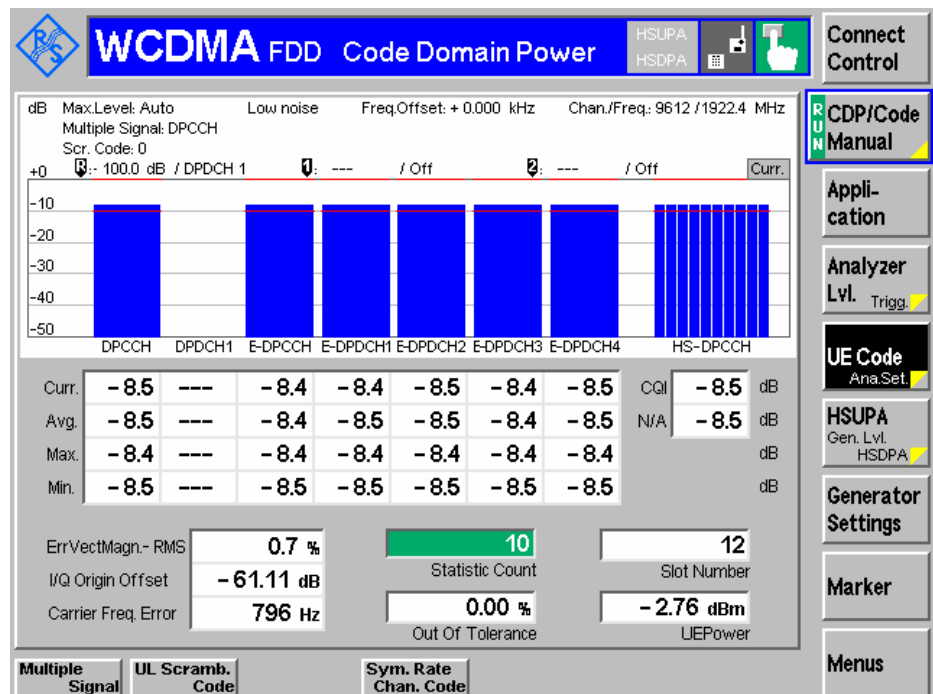


Figure 31 Manual code domain view of HSUPA signal on CMU200

### **Demo Software for HSDPA measurements**

This application note comes with a small demo program called “GDE” (Generic Demonstration Engine). The software is running on a PC. For installing it, download and start the file 1MA84\_1.0.exe which will guide you through the installation process.

The GDE is a remote control command sequencer tool. It offers a user interface for setting basic parameters of an HSDPA signal with DPCCH, DPDCH, and HS-DPCCH, and for measuring ACLR, crest factor, or composite EVM of this signal. After selecting the measurement of interest and configuring the parameters, R&S instruments like SMU200A and FSQ are preconfigured via remote control, and the measurement is done automatically. Figure 32 shows the user interface of the GDE.

Within the Help menu (Help for GDE general), a detailed explanation of the software can be found.

You can select from crest factor measurement, ACLR measurement, or composite EVM measurement (1). For editing the test setup, select (2). A test editor as shown in figure 33 opens up.

## HSDPA & HSUPA: Challenges for UE Power Amplifier Design

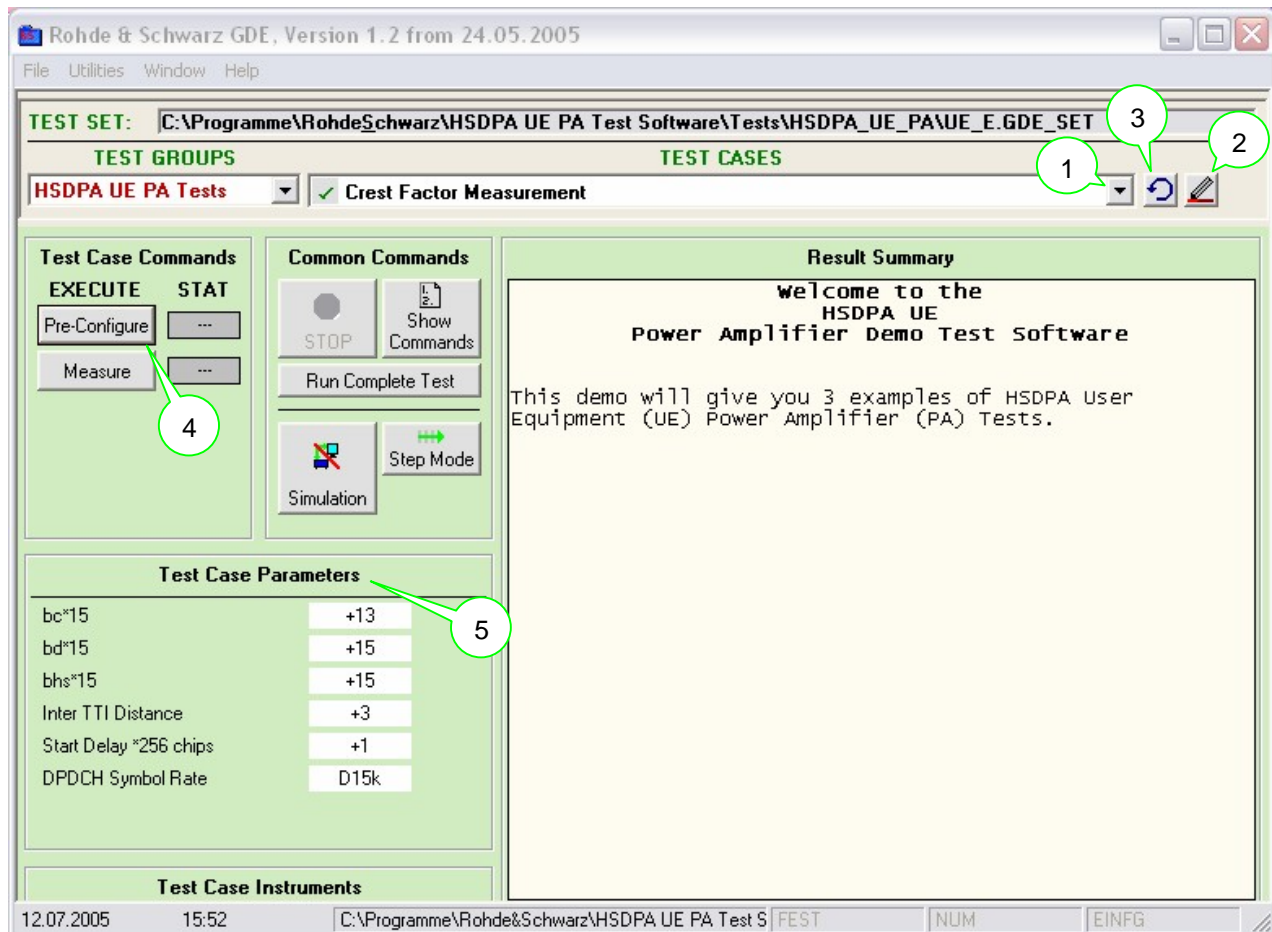


Figure 32 - User Interface of GDE, Crest Factor measurement selected

The text editor allows to input values for  $\beta_c$ ,  $\beta_d$  and  $\beta_{hs}$  (called bc, bd and bhs in this program), which are then automatically converted to the correct level setting in the SMU200A. Note that for simplicity all beta factors are assumed to be relative to the amplitude factor 1/15 in this user interface. This also reflects the gain factor settings requested for the test cases in [12]. However, for correctly determining the values, you have to be aware that the beta factor of HS-DPCCH is defined relative to the beta factor of DPCCH, see table 15. In case of no HS-DPCCH or no DPDCH signal, insert bhs = 0 or bd = 0, respectively.

## HSDPA & HSUPA: Challenges for UE Power Amplifier Design

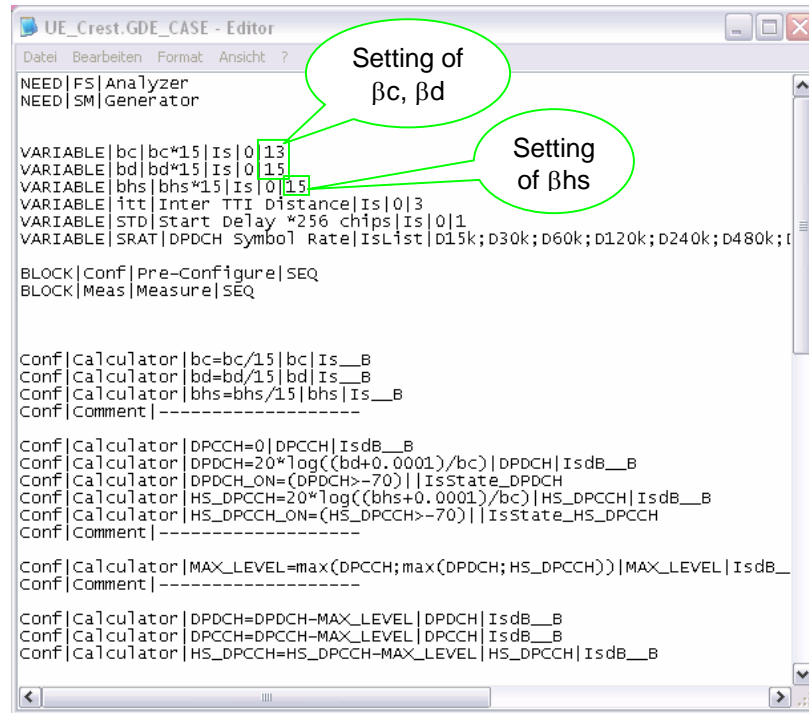


Figure 33 - Editing a test setup with the GDE

Besides beta factors, also inter TTI distance, start delay, and DPDCH symbol rate can be set. The DPDCH symbol rate can be conveniently selected in a list (figure 34).

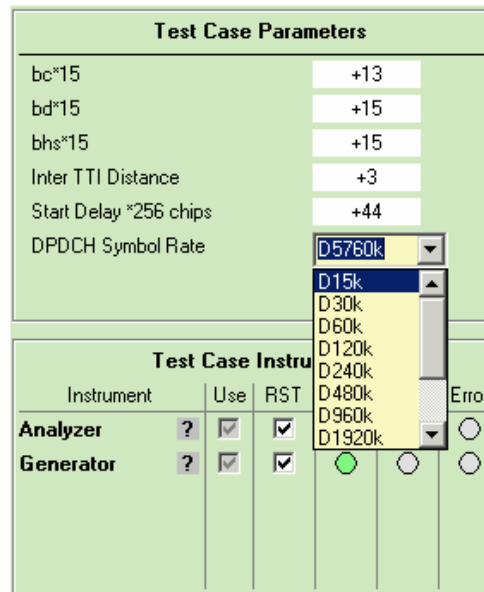


Figure 34 - User Selection of DPDCH symbol rate

The test setup file can easily be customized to enable more settings, based on the remote control commands for SMU200A and FSQ.

When you have saved your settings, reload the test setup ((3) in figure 32), pre-configure the instruments and do the measurement ((4) in figure 32). The relevant test case parameters are displayed in the user interface ((5) in figure 32).

## 5 Abbreviations

3GPP	3rd Generation Partnership Project
ACK	Acknowledgement
ACLR	Adjacent Channel Leakage Ratio
AMR	Adaptive Multirate Codec
ARQ	Automatic Repeat Request
BLER	Block Error Rate
CCDF	Complementary Cumulative Distribution Function
CM	Cubic Metric
CQI	Channel Quality Indicator
DPCCH	Dedicated Physical Control Channel
DPCH	Dedicated Physical Channel
DPDCH	Dedicated Physical Data Channel
DTX	Discontinuous Transmission
DUT	Device under Test
E-DCH	Enhanced Dedicated Channel
E-DPCCH	E-DCH Dedicated Physical Control Channel
E-DPDCH	E-DCH Dedicated Physical Data Channel
E-TFCI	E-DCH Transport Format Combination Indicator
EUL	Enhanced Uplink
EVM	Error Vector Magnitude
FDD	Frequency Division Duplex
HARQ	Hybrid Automatic Repeat Request
HSDPA	High Speed Downlink Packet Access

## ***HSDPA & HSUPA: Challenges for UE Power Amplifier Design***

HS-DSCH	High Speed Downlink Shared Channel
HS-DPCCH	High Speed Dedicated Physical Control Channel
HS-PDSCH	High Speed Physical Downlink Shared Channel
HS-SCCH	High Speed Shared Control Channel
HSUPA	High Speed Uplink Packet Access
MAC	Medium Access Control
MPR	Maximum Power Reduction
NACK	Negative Acknowledgement
NAS	Non-Access Stratum
PAR	Peak-to-Average Ratio
P-CCPCH	Primary Common Control Physical Channel
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
TFC	Transport Format Combination
TFCI	Transport Format Combination Indicator
TS	Technical Specification
TTI	Transmission Time Interval
UE	User Equipment
UMTS	Universal Mobile Telecommunications System
WCDMA	Wideband Code Division Multiple Access

### 6 Additional Information

This application note is updated from time to time. Please visit the website [1MA84](#) in order to download new versions.

Please contact [TM-Applications@rsd.rohde-schwarz.com](mailto:TM-Applications@rsd.rohde-schwarz.com) for comments and further suggestions.

### 7 References

- [1] Application Note 1MA82; HSDPA Test and Measurement Requirements, Rohde & Schwarz
- [2] Application Note 1MA94; High Speed Uplink Packet Access (HSUPA) White Paper, Rohde & Schwarz
- [3] 3GPP TS 25.211; Physical channels and mapping of transport channels onto physical channels (FDD) (Release 6)
- [4] 3GPP TS 25.212; Multiplexing and Channel Coding (FDD) (Release 6)
- [5] 3GPP TS 25.213; Spreading and Modulation (FDD) (Release 6)
- [6] 3GPP TS 25.214; Physical layer procedures (FDD) (Release 6)
- [7] 3GPP TS 25.101; User Equipment Radio Transmission and Reception (FDD) (Release 5)
- [8] 3GPP TS 25.101; User Equipment Radio Transmission and Reception (FDD) (Release 6)
- [9] R4-030796; ACLR Requirements under HSDPA Operation, SEMC
- [10] RP-040113; UE maximum power reduction when HS-DPCCH is transmitted, Nokia
- [11] R4-040102; HSDPA PA Back-off, Motorola
- [12] 3GPP TS 34.121; Terminal conformance specification ; Radio transmission / reception (FDD) (Release 7)
- [13] R4-040367; Comparison of PAR and Cubic Metric for Power Degrating, Motorola
- [14] R4-040721; Mapping of cubic metric to additional PA headroom, Qualcomm

**[15]** 3GPP TS 25.321; Medium Access Control (MAC) protocol specification (Release 6)

**[16]** 3GPP TS 25.141; Base Station (BS) conformance testing (FDD) (Release 6)

## 8 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-B9	Baseband Generator with digital modulation (realtime) and ARB (128 M Samples)	1161.0766.02
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-K43	3GPP FDD enhanced MS/BS Tests incl. HSDPA	1160.9660.02
R&S® SMU-K45	3GPP FDD HSUPA	1161.0666.02
R&S® SMU-K242	3GPP FDD for WinIQSIM2	1408.5618.02
R&S® SMU-K243	3GPP FDD enhanced MS/BS tests incl. HSDPA for WinIQSIM2	1408.5718.02
R&S® SMU-K245	Digital standard HSUPA for WinIQSIM2	1408.5918.02
R&S® SMJ100A		1403.4507.02
R&S® SMJ-B103	Frequency range 100 kHz - 3 GHz	1403.8502.02
R&S® SMJ-B106	Frequency range 100 kHz - 6 GHz	1403.8702.02
R&S® SMJ-B9	Baseband generator with digital modulation (realtime) and ARB (128 M Samples)	1404.1501.02



## HSDPA & HSUPA: Challenges for UE Power Amplifier Design

R&S® SMJ-B10	Baseband Generator with digital modulation (realtime) and ARB (64MSamples)	1403.8902.02
R&S® SMJ-B11	Baseband Generator with digital modulation (realtime) and ARB (16MSamples)	1403.9009.02
R&S® SMJ-B13	Baseband Main Module	1403.9109.02
R&S® SMJ-K42	Digital Standard 3GPP FDD	1404.0405.02
R&S® SMJ-K43	3GPP FDD Enhanced MS/BS Tests incl. HSDPA	1404.0505.02
R&S® SMJ-K45	3GPP FDD HSUPA	1409.1816.02
R&S® SMJ-K242	Digital standard 3GPP FDD for WinIQSIM2	1409.0610.02
R&S® SMJ-K243	3GPP FDD enhanced MS/BS Tests incl. HSDPA for WinIQSIM2	1409.0710.02
R&S® SMJ-K245	Digital standard HSUPA	1409.0910.02
R&S® SMATE200A		1400.7005.02
R&S® SMATE-B103	Frequency range 100 KHz to 3 GHz for 1st RF Path	1401.1000.02
R&S® SMATE-B106	Frequency range 100 KHz to 6 GHz for 1st RF Path	1401.1200.02
R&S® SMATE-B203	Frequency range 100 KHz to 3 GHz for 2nd RF Path	1401.1400.02
R&S® SMATE-B206	Frequency range 100 kHz - 6 GHz for 2nd RF path	1401.1600.02
R&S® SMATE-B10	Baseband Generator with digital modulation (realtime) and ARB (64MSamples)	1401.2707.02
R&S® SMATE-B11	Baseband Generator with digital modulation (realtime) and ARB (16MSamples)	1401.2807.02
R&S® SMATE-B13	Baseband Main Module	1401.2907.02
R&S® SMATE-K42	Digital Standard 3GPP FDD	1404.5207.02
R&S® SMATE-K43	3GPP FDD Enhanced MS/BS Tests incl. HSDPA	1404.5307.02
R&S® SMATE-K45	3GPP FDD HSUPA	1404.7300.02

### 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

## HSDPA & HSUPA: Challenges for UE Power Amplifier Design

R&S® FS-K73      Application Firmware 3GPP-FDD UE Transmitter 1154.7252.02  
Test for FSMR, FSP, FSU, FSQ

### Universal Radio Communication Tester (UE)

R&S® CMU200		1100.0008.02
R&S®CMU-B68var02	HW-option for CMU200 layer 1-board (3GPP/FDD, DL+UL)	1149.9809.02
R&S®CMU-B21var54	HW-option for CMU200/300: (GSM/GPRS/EDGE)	1100.5200.54
R&S® CMU-B56	HW-option for CMU200: WCDMA and data E2E for CMU-B21/var. 14	1150.1850.14
R&S® CMU-PK60	Software option for CMU200: WCDMA-Sig.: 3GPP/FDD/UE, TX-test generator, band 1-9	1159.3355.04
R&S® CMU-K64	SW-option for CMU200: HSDPA 3GPP	1157.3970.02
R&S® CMU-K60	SW option for CMU200: HSDPA 10Mbps ext.	1200.8200.02
R&S® CMU-K56	SW option for CMU200: HSUPA 5.7Mbps	1200.7803.02



**ROHDE & SCHWARZ**

ROHDE & SCHWARZ GmbH & Co. KG · Mühlhofstraße 15 · D-81671 München · P.O.B 80 14 69 · D-81614 München ·

Telephone +49 89 4129 -0 · Fax +49 89 4129 - 13777 · Internet: <http://www.rohde-schwarz.com>

*This application note and the supplied programs may only be used subject to the conditions of use set forth in the download area of the Rohde & Schwarz website.*