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Contents

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Special Mobile Group (SMG).
The present document has been elaborated by the Layer 1 expert group of SMG2 "Radio aspects", as a part of the work in defining and describing Layer 1 of the Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access (UTRA).
The present document describes the physical layer procedures in UTRA/FDD.

1 Scope

This Technical Report establishes the characteristics of the physicals layer procedures in the FDD mode of UTRA. The main objectives of the document are to be a part of the full description of the UTRA Layer 1, and to serve as a basis for the drafting of the actual technical specification (TS).

2 References

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

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies.
- A non-specific reference to an ETS shall also be taken to refer to later versions published as an EN with the same number.

[1] Reference 1.

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document the following terms and definitions apply:
Definition 1: to be completed

3.2 Symbols

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

<symbol> <Explanation>

3.3 Abbreviations

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

BCH	Broadcast Channel
CCPCH	Common Control Physical Channel
DCH	Dedicated Channel
DPCCH	Dedicated Physical Control Channel
DPCH	Dedicated Physical Channel
DPDCH	Dedicated Physical Data Channel
FACH	Forward Access Channel
MUI	Mobile User Identifier
PCH	Paging Channel
PI	Paging Indication
PRACH	Physical Random Access Channel
RACH	Random Access Channel
SCH	Synchronisation Channel
SIR	Signal-to-Interference Ratio
SSDT	Site Selection Diversity TPC
TPC	Transmit Power Control
UE	User Equipment

4 Power control

< Documentation status: Everything in this section is to be considered as working assumption, except otherwise explicitly stated. >

4.1 Uplink power control

4.1.1 Closed loop power control

4.1.1.1 General

The uplink closed loop power control adjusts the UE transmit power in order to keep the received uplink Signal-to-Interference Ratio (SIR) at a given SIR target.

The serving cells (cells in the active set) should estimate the received uplink DPCCH power after RAKE combining of the connection to be power controlled. Simultaneously, theserving cells should estimate the total uplink received interference in the current frequency band and generate a SIR estimate SIR_{est}. The serving cells then generates TPC commands according to the following rule:

$SIR_{est} > SIR_{target,UL} \rightarrow$ TPC command = 1

$SIR_{est} < SIR_{target,UL} \rightarrow$ TPC command = 0

If multiple TPC commands are received, then upon reception of these TPC commands, the UE combines the received commands into a single TPC command. The combination process depends on whether the transmitted TPC commands are known to be the same or are known to be possibly different. The combination process for each of these two cases is described in subclauses 4.1.1.2 and 4.1.1.3 respectively.

The UE then adjusts the transmit power of both the uplink DPCCH and the uplink DPDCH with a step of Δ_{TPC} dB according to the TPC command, where the TPC command is the result of combination in the case of multiple received commands . If TPC=1 then the transmit power of the uplink DPCCH and uplink DPDCH is increased by Δ_{TPC} dB. If TPC=0 then the transmit power of the uplink DPCCH and uplink DPDCH is decreased by Δ_{TPC} dB.

The step size Δ_{TPC} is a parameter that may differ between different cells, in the region 0,25 – 1,5 dB. In the event different step sizes are used in the different serving cells, then the transmit power change should take into account the TPC obtained by combining individual commands and the different step sizes, and should be one of the allowed step sizes (FFS).

4.1.1.2 Combining of TPC commands known to be the same

In some cases, the UE has the knowledge that some of the transmitted TPC commands are the same. This is the case e.g. with receiver diversity (e.g., space diversity) or so called softer handover when the UTRAN transmits the same command in all the serving cells the UE is in softer handover with. For these cases, the TPC commands known to be the same are maximum ratio combined into one TPC command.

4.1.1.3 Combining of TPC commands not known to be the same

In general in case of soft handover, the TPC commands transmitted in the different cells may be different.

This section describes the general scheme for combination of the TPC commands known to be different and then provides an example of such scheme. It is to be further decided what should be subject to detailed standardisation, depending on final requirements. The example might be considered as the scheme from which minimum requirement will be derived or may become the mandatory algorithm.

4.1.1.3.1 General scheme

- The UE should estimate the signal-to-interference ratio PC_SIR_i on each of the power control command TPC_i, , where i=1,…N and N is the number of TPC commands known to be different, that may be the results of a first phase of combination according to subclause 4.1.1.2.
- The UE should assign to each of the TPC_i command a reliability figure W_i, where W_i is a function β of PC_SIR_i , $W_i = \beta (PC\_SIR_i)$.
- The UE should derived a combined TPC command, noted TPC, as a function γ of all the N power control commands TPC_i and reliability estimates W_i. TPC= $\gamma (W_1, W_2, \ldots W_N, TPC_1, TPC_2, \ldots TPC_N)$, where TPC=0 or 1, as in absence of soft handover.
- The UE should then change its power as described in subclause 4.1.1.1.

4.1.1.3.2 Example of the scheme

A particular example correspond to the following definition of the function β and γ:

For β: the reliability figure W_i is set to 0 if PC_SIR_i <PC_thr, otherwise W_i is set to 1. This means that the power control command is assumed unreliable if the signal to interference ratio of the TPC bits is lower than a minimum value PC_thr.

For γ: if there is al least one TPC_i command, for which W_i=1 and TPC_i=0, then TPC=0, otherwise TPC=1. Such a function γ means that the power is decreased if at least one base station for which the reliability criterion is satisfied asks for a power decrease.

4.1.2 Outer loop (SIR target adjustment)

The outer loop adjusts the SIR target used by the closed-loop power control. The SIR target is independently adjusted for each connection based on the estimated quality of the connection. In addition, the power offset between the uplink DPDCH and uplink DPCCH may be adjusted. How the quality estimate is derived and how it affects the SIR target is decided by the radio-resource management, i.e. it is not a physical-layer issue.
In soft handover, the quality threshold for the cells in the active set should be adjusted by the outer loop power control (to be implemented in the network node where soft handover combining is performed).

4.1.3 Open-loop power control

Open-loop power control is used to adjust the transmit power of a random-access burst on the PRACH. Before the transmission of a random-access burst, the UE should measure the received power of the downlink Primary CCPCH over a sufficiently long time to remove effects of the non-reciprocal multi-path fading. From the power estimate and knowledge of the Primary CCPCH transmit power (broadcast on the BCH) the downlink path-loss including shadow fading can be found. From this path loss estimate and knowledge of the uplink interference level and the required received SIR, the transmit power of the random-access burst can be determined. The uplink interference level as well as the required received SIR are broadcast on the BCH.

4.2 Downlink power control

4.2.1 Closed loop power control

The downlink closed loop power control adjusts the Node B transmit power in order to keep the received downlink SIR at a given SIR target.
The UE should estimate the received downlink DPCH power after RAKE combining of the connection to be power controlled. Simultaneously, the UE should estimate the total downlink received interference in the current frequency band. The UE then generates TPC commands according to the following rule:
$SIR_{est} > SIR_{target,DL} \rightarrow$ TPC command = "down"
$SIR_{est} < SIR_{target,DL} \rightarrow$ TPC command = "up"
Upon the reception of a TPC command, the Node B should adjust the transmit power in the given direction with a step of Δ_{TPC} dB. The step size Δ_{TPC} is a parameter that may differ between different cells, in the range 0,25 – 1,5 dB.
In case of receiver diversity (e.g., space diversity) at the UE, the TPC command should be generated after diversity combining.

4.2.2 Outer loop (SIR target adjustment)

The outer loop adjusts the SIR target used by the closed-loop power control. The SIR target is independently adjusted for each connection based on the estimated quality of the connection. In addition, the power offset between the downlink DPDCH and DPCCH may be adjusted. How the quality estimate is derived and how it affects the SIR target is decided by the radio-resource management, i.e. it is not a physical-layer issue.

4.2.3 Site selection diversity transmit power control (SSDT)

Site selection diversity transmit power control (SSDT) is an optional macro diversity method in soft handover mode. Operation is summarised as follows. The user equipment (UE) selects one of the cells from its active set to be ‘primary’, all other cells are classed as ‘non primary’. The main objective is to transmit on the downlink from the best cell, thus reducing the interference caused by multiple transmissions in a soft handover mode. A second objective is to achieve fast site selection without network intervention, thus maintaining the advantage of the soft handover. In order to select a primary cell, each cell is assigned a temporary identification and UE periodically informs a primary cell identification to the connecting cells. The non-primary cells selected by UE switch off the transmission power. The primary cell identity code is delivered via vacant uplink TPC bits prepared by the puncture method described in XX.07, subclause 4.2.3.5.

4.2.3.1 Initiation of SSDT

The SSDT is initiated by network (RNC), based on the soft handover active cell set. The cell and UE are subsequently informed by RNC that the SSDT option has been activated during the current soft handover period. Otherwise, TPC is

operated in the ordinary mode: i.e. each cell controls its power in accordance with an uplink TPC command by the way described in 4.2.1. The temporary cell identification assignment (i.e. ID code assignment) is based on the order of active set (present at RNC) which is communicated to all the active cells and the UE.
A cell receiving the active list is capable of recognising its entry position in the list from which it can determine its own ID code. Similarly, UE upon receiving the active list can determine the ID code of each of the active cells according to the order of the cell entries in the list. Therefore the RNC, cell and UE has the same association between the ID codes and cells. After the activation of the SSDT and the subsequent UE acknowledgements, UE starts to send the "Primary" cell ID code, described in the following sections. Following a successful activation of SSDT and reception of the UE acknowledgement, the active cells start detecting the "primary" cell ID information.

4.2.3.2 Settings of temporary cell identification

Each cell is given a temporary identification during SSDT and the identification is utilised as site selection signal. In the following, the temporary identification is referred to as "ID".

4.2.3.2.1 Definition of temporary cell identification

The ID is given a binary bit sequence with the length of N_{BID} bits. The parameter N_{BID} can take the value 4 or 8 bits. Setting examples of ID codes are exhibited in Table 1.

Table 1: Setting examples of ID codes

	ID code	
ID label	**N_{BID} =8**	**N_{BID} =4**
a	00000000	0000
b	11111111	1111
c	00001111	0011
d	11110000	1100
e	00111100	0110
f	11000011	1001

4.2.3.2.2 Assignment of ID to each cell

The "ID" word assignment is based on the entry position in the active list, which is compiled and communicated to all active cells and UE.

Table 2: ID assignment example

The number of cells in an active set	ID label assignment for each cell					
	Entry position in active set					
	1	2	3	4	5	6
1	a					
2	a	b				
3	a	b	c			
4	a	b	c	d		
5	a	b	c	d	e	
6	a	b	c	d	e	f

4.2.3.2.3 Notification of ID assignment change

Every time that the active list is changed, it is up dated and communicated to all active cells and UE.

4.2.3.3 TPC procedure in UE

TPC procedure of UE in SSDT is identical to that described in subclause 4.2.1.

4.2.3.4 Selection of primary cell

The UE selects a primary cell periodically by measuring reception levels of common pilots transmitted by the active cells. The cell with the highest pilot power is detected as a primary cell.

4.2.3.5 Delivery of primary cell ID

UE periodically sends the ID code of the primary cell via vacant TPC bits given by the puncture method described here. A cell recognises its state as non-primary if the following two conditions are fulfilled simultaneously:

- The received primary ID code does not match with the own ID code.

- The received uplink signal quality satisfies a quality threshold, Qth (parameter defined by network operator).

Otherwise the cell recognises its state as primary.

At the UE, the primary ID code to be sent to the cells is segmented into a number of portions. These portions are distributed in the vacant TPC bit fields given by the puncture method. cell in SSDT collects the distributed portions of the primary ID code and then detects the transmitted ID. There are two TPC puncture methods as shown in Table 3.

Table 3: TPC puncturing methods

	The number of punctured bits in a TPC symbol	Period of puncturing	Period of primary cell update	
			8bit ID code	4bit ID code
case 1	1 bit	every slot	every 8 slots	every 4 slots
case 2	2 bits	every 4 slots	every 16 slots	every 8 slots

In case 1, one bit of one TPC symbol is punctured every slot and thus, for example, it takes 8 slots to send 8 bit ID code. In case 2, 2 bits of one TPC symbol are punctured every 4 slots.

4.2.3.6 TPC procedure in cell

In SSDT, a non-primary cell can switch off its output power (i.e. no transmissions). TPC bits carrying portion of the primary ID code should be neglected in detecting power up / down signal. If the entire TPC symbol within a slot has been replaced by the portion of primary ID code, the downlink transmission power in the corresponding slot should hold the previous one.

4.2.3.6.1 Management of multiple transmission power levels

The cell manages two transmission power levels, P1, and P2. A cell keeping minimum power level would know the required transmit power by referring to P1 if selected as the primary cell. A cell updates P1 regardless of the selected choice. Level P2 is the actual transmission power level for non-primary cell. When a cell is selected by UE as the primary cell, P2 is set to P1, otherwise the cell maintains P2 at the minimum transmit level (i.e. switched off). P1, and P2, expressed in dBm, are updated in accordance with TPC commands from UE as shown in Table 4. The two power settings, P1 and P2 are maintained within the power control dynamic range.

Table 4: Updating of P1 and P2

state of cell	TPC signal	P1	P2
non primary	down	P1 - Δ_{TPC}	Switched off
	up	P1 + Δ_{TPC}	Switched off
primary	down	P1 - Δ_{TPC}	=P1
	up	P1 + Δ_{TPC}	=P1

Δ_{TPC} is defined in subclause 4.2.1. No regulation of initial value of P1and P2 is given.

4.2.3.6.2 Power setting of the downlink Dedicated Physical Channel

The downlink Dedicated Physical Channel is partitioned into 4 portions as shown in Figure 10 of UMTS XX.03. Power setting of each portion during SSDT is depicted in Figure 1.

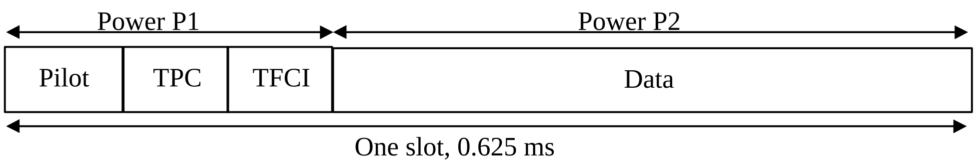

Figure 1: Power setting of the downlink Dedicated Physical Channel

Transmission power of the TPC and TFI portions are always set to P1, in order to detect the control information at the UE with high reliability.

4.2.3.7 Termination of SSDT

The decision to terminate the SSDT is made at RNC, based on the UE reported received signal strength levels of all the active and candidate list pilots. The termination request should be informed by RNC to both cells and UE in the same way as soft handoff termination process.

5 Cell search

< Documentation status: Everything in this section is to be considered as working assumption, except otherwise explicitly stated. >

5.1 Initial cell search

During the initial cell search, the UE searches for the cell to which it has the lowest path loss. It then determines the downlink scrambling code and frame synchronisation of that cell. The initial cell search uses the synchronisation channel (SCH), shown in Figure 2 below (repeated from UMTS XX.03).

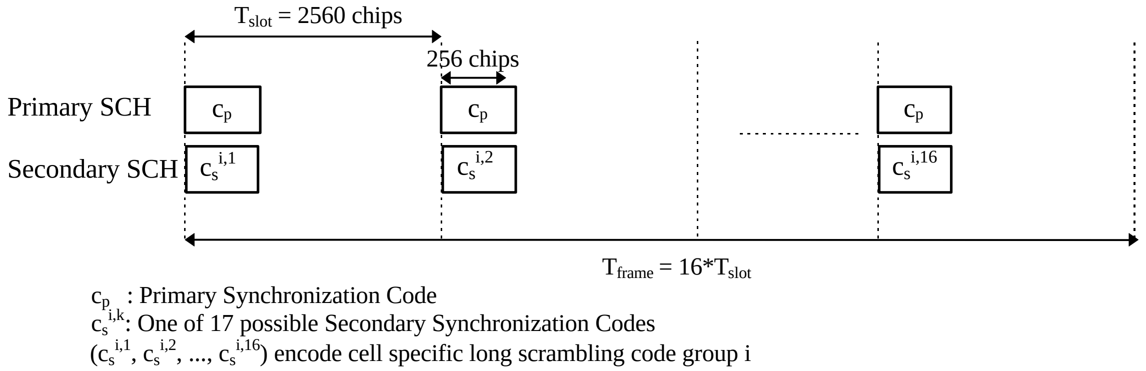

Figure 2: Structure of synchronisation channel (SCH)

This initial cell search is carried out in three steps:

Step 1: Slot synchronisation

During the first step of the initial cell search procedure the UE uses the primary SCH to acquire slot synchronisation to the strongest cell. This is done with a single matched filter (or any similar device) matched to the primary synchronisation code c_p which is common to all cells. The output of the matched filter will have peaks for each ray of each cell within range of the UE, see Figure 3. Detecting the position of the strongest peak gives the timing of the strongest cell modulo the slot length. For better reliability, the matched-filter output should be accumulated over a number of slots.

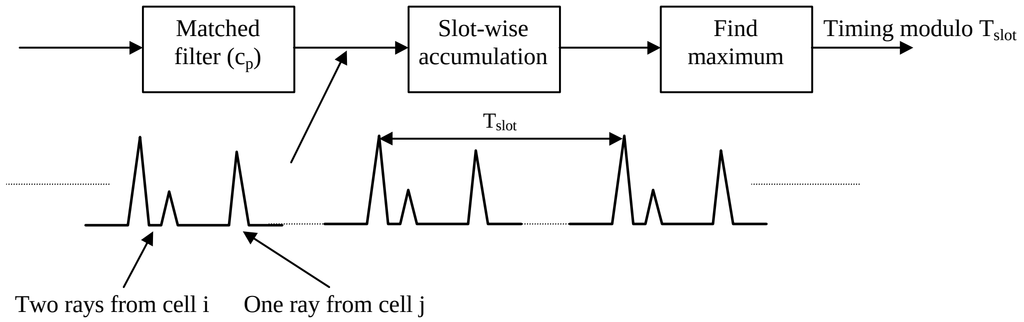

Figure 3: Matched-filter search for primary synchronisation code to slot synchronisation (timing modulo the slot length)

Step 2: Frame synchronisation and code-group identification

During the second step of the initial cell search procedure, the UE uses the secondary SCH to find frame synchronisation and identify the code group of the cell found in the first step. This is done by correlating the received signal at the positions of the Secondary Synchronisation Code with all possible (17) Secondary Synchronisation Codes. Note that the position of the Secondary Synchronisation Code is known after the first step. The outputs of all the 17 correlators for 16 consecutive secondary SCH locations are used to form the decision variables. The decision variables are obtained by combining the correlator outputs corresponding to each 16 length sequence out of the 32 possible sequences and its 16 cyclic shifts giving a total of 512 decision variables. Note that the cyclic shifts of the sequences are unique (see UMTS XX.03). Thus, by identifying the sequence/shift pair that gives the maximum correlation value, the code group as well as the frame synchronisation is determined.

Step 3: Scrambling-code identification

During the third and last step of the initial cell-search procedure, the UE determines the exact primary scrambling code used by the found cell. The primary scrambling code is identified through symbol-by-symbol correlation over the Primary CCPCH with all codes within the code group identified in the second step. Note that, from step 2, the frame boundary and consequently the start of the primary scrambling code is known. Correlation must be carried out symbol-wise, due to the unknown data of the primary CCPCH. Also, in order to reduce the probability of wrong/false acquisition, due to background noise/interference, averaging the correlator outputs over a sequence of symbols might be required before using the outputs to determine the exact scrambling code.
After the primary scrambling code has been identified, the Primary CCPCH can be detected, super-frame synchronisation can be acquired and the system- and cell specific BCH information can be read.

5.2 Idle mode cell search

When in idle mode, the UE continuously searches for new cells on the current and other carrier frequencies. The cell search is done in basically the same way as the initial cell search. The main difference compared to the initial cell search is that a UE has received a priority list from the network. This priority list describes in which order the downlink scrambling codes should be searched for and does thus significantly reduce the time and effort needed for the scrambling-code search (step 3). Also the complexity in the second step may be reduced if the priority list only includes scrambling codes belonging to a subset of the total set of code groups. The priority list is continuously updated to reflect the changing neighbourhood of the moving UE.

5.3 Active mode cell search

When in active mode, the UE continuously searches for new base stations on the current carrier frequency. This cell search is carried out in basically the same way as the idle mode cell search. The UE may also search for new cells on other carrier frequencies using the slotted mode, see UMTS XX.15.

6 Random access

< Documentation status: The random access procedure is to be considered a working assumption, however some details are for further study. >

The procedure of a random access request is:

1 The UE acquires synchronisation to a cell
2 The UE reads the BCH to get information about:
  2.1 The preamble spreading code(s) / message scrambling code(s) used in the cell
  2.2 The available signatures
  2.3 The available access slots
  2.4 The available spreading factors for the message part
  2.5 The uplink interference level in the cell
  2.6 The primary CCPCH transmit power level
3 The UE selects a preamble spreading code/message scrambling code
4 The UE selects a spreading factor for the message part
5 The UE estimates the downlink path loss (by using information about the transmitted and received power level of the primary CCPCH), and determines the required uplink transmit power (by using information about the uplink interference level in the cell)
6 The mobile implements the dynamic persistence algorithm by:
  6.1 Reading the current dynamic persistence value from the BCH
  6.2 Perform a random draw against the current dynamic persistence value
  6.3 Defer transmission for one frame and repeat step 6 if the result of the random draw is negative, otherwise proceed to step 7
7 The UE randomly selects an access slot and signature from the available access slots and signatures
8 The UE transmits its preamble
9 If the UE does not detect an acquisition indicator with the selected signature in the next access slot, the UE retransmits the preamble with a re-selected signature in the next available access slot with a pre-defined change of transmit power and repeat step 9
10 The UE transmits its random access message in the next available access slot
11 The UE waits for an acknowledgement from the network side. If no acknowledgement is received within a predefined time-out period, the UE starts again from step 5

Dynamic persistence is provided for managing interference and minimising delay by controlling access to the RACH channel. The system will publish a dynamic persistence value on the BCH, the value of which is dependent on the estimated backlog of users in the system.
A typical implementation of the random-access receiver for a given preamble code and signature is illustrated in Figure 4. The received signal is fed to a matched filter, matched to the preamble code. The output of the matched filter is then correlated with the signature. The output of the preamble correlator will have peaks corresponding to the timing of any received random-access burst using the specific preamble code and signature. The estimated timing can then be used in a ordinary RAKE combiner for the reception of the data part of the random-access burst.

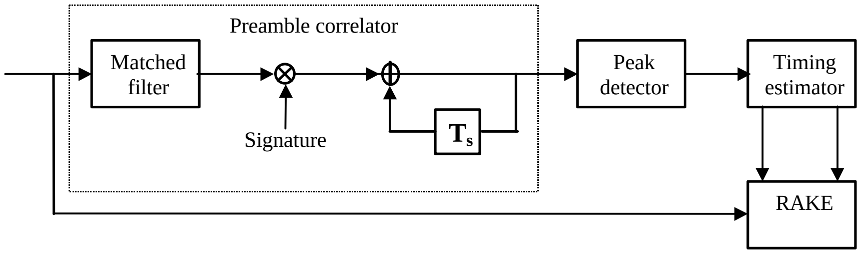

Figure 4: Random-access receiver

Upon reception of the random-access burst, the network responds with an Access Grant message on the FACH. In case the random-access request is for a dedicated channel (circuit-switched or packet) and the request is granted, the Access Grant message includes a pointer to the dedicated physical channel(s) to use. As soon as the UE has moved to the dedicated channel, closed-loop power control is activated.

7 Idle mode tasks

< Documentation status: Everything in this section is to be considered as working assumption, except otherwise explicitly stated. >

7.1 Paging control

< Documentation status: The paging control procedure is to be considered a proposal. >

7.1.1 Network operation

Every UE belongs to one group. When there exists a paging message for the UE, the paging message is transmitted on the PCH in the MUI-parts belonging to the UE's group. The paging message includes the mobile station identification number of the UE for which the paging message was intended. When a MUI is transmitted, the corresponding PI1 and PI2 fields are also transmitted.
The exact behaviour of the network is described as:
For the PCH of the group which does not have a paging message:

- The network shall transmit the two PI parts (PI1 and PI2) in the PCH as "all 0".
- The MUI part shall not be transmitted.

For the PCH of the group which have a paging message:

- The network shall transmit the two PI parts (PI1 and PI2) in the PCH as "all 1".
- The MUI part shall be transmitted within the same PCH.

7.1.2 UE operation

The idea behind the detection of paging messages is to open the receiver to detect one of or both the paging indicators (PI1 and PI2), and if they indicate a paging message for the group the UE belongs to, the actual paging information part (MUI) is received. When the MUI part is received, the existence of a paging message for the UE is determined from the information included in the MUI part.
The UE operation for detection of paging information in group *n* is shown in Figure 5. $PI1_n$, $PI2_n$, and MUI_n are the PCH components belong to group *n*.

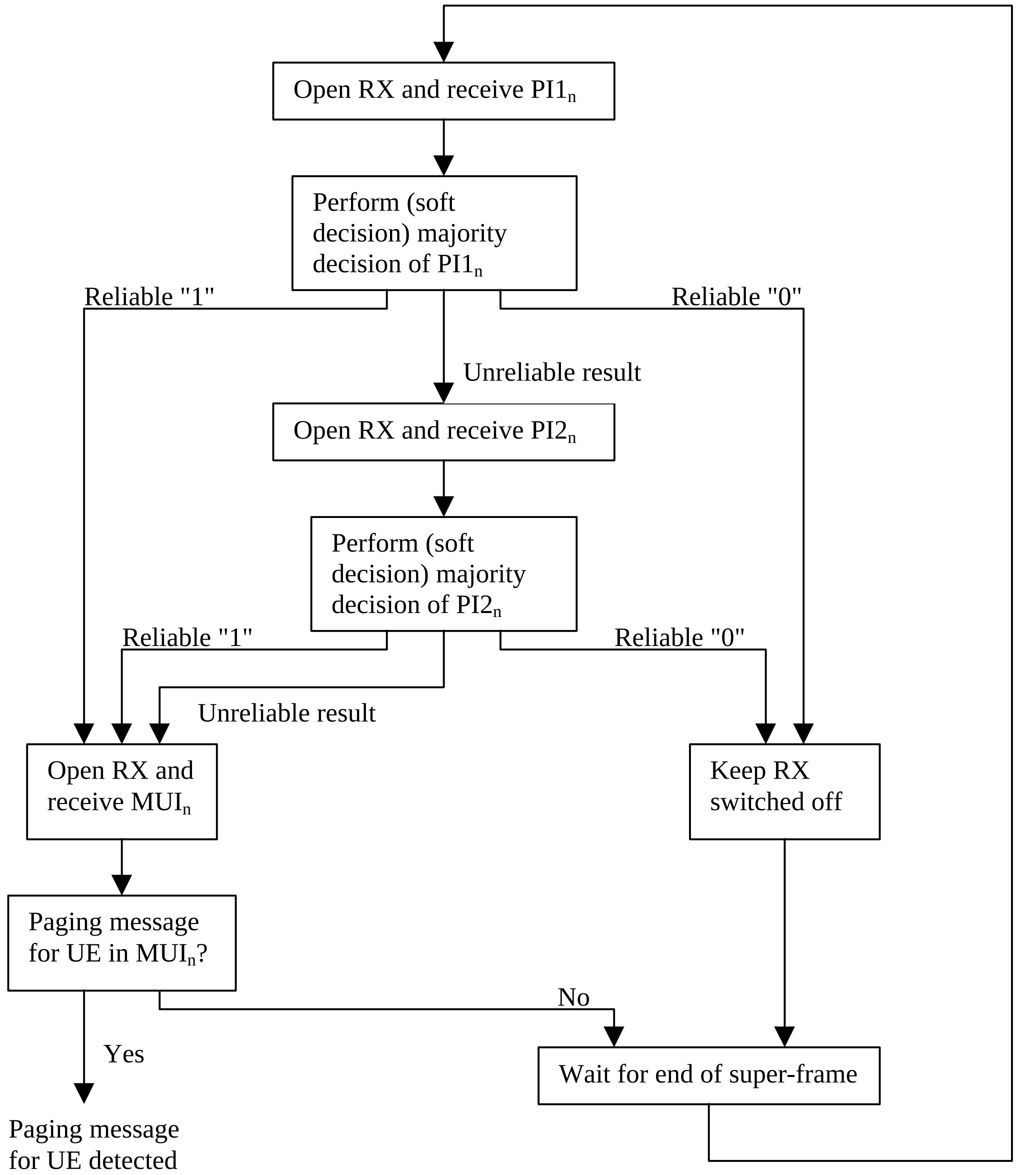

Figure 5: Detection of paging messages

8 Feedback mode transmit diversity

8.1 DPCH transmission scheme

The transmitter structure to support Feedback (FB) Mode Transmit Diversity for DPCH transmission is shown in Figure 6. Channel coding, interleaving and spreading are done as in non-diversity mode. The spread complex valued signal is fed to both TX antenna branches, and weighted with antenna specific weight factors w_1 and w_2. The weight factors are complex valued signals (i.e., $w_i = a_i + jb_i$), in general. In a special case, the weights w_1 and w_2 can have values 0 (1) and 1(0), respectively, which corresponds to antenna switching.
The weight factors are determined by the UE, and signalled to the UTRAN access point (=cell transceiver) through the uplink DPCCH.

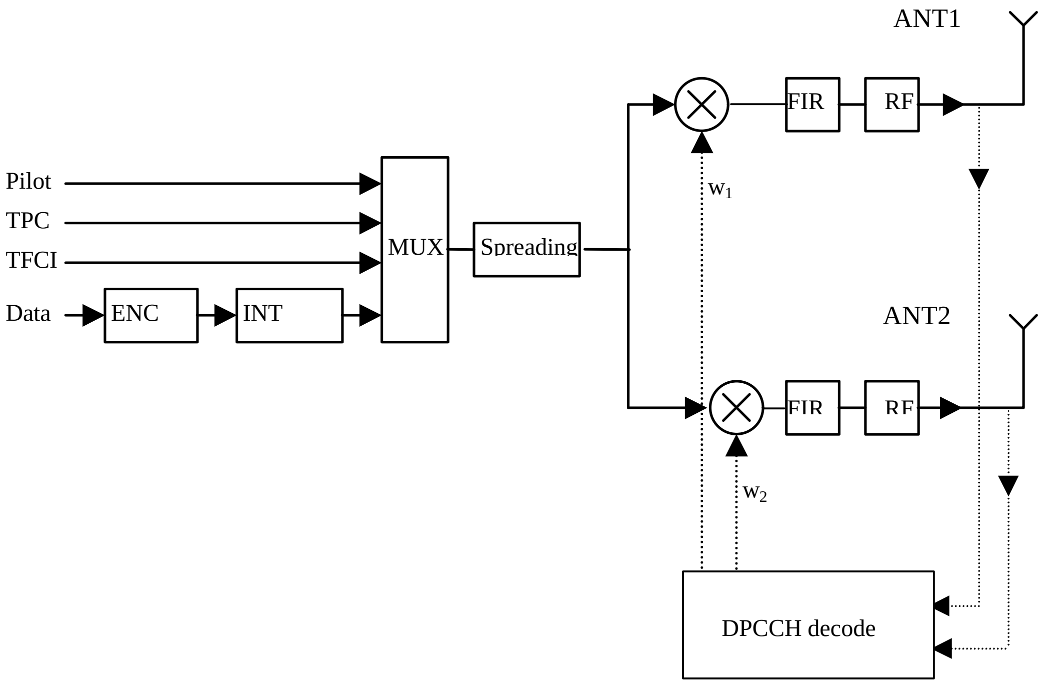

Figure 6: Downlink transmitter structure to support FB Mode Transmit Diversity for DPCH transmission (UTRAN Access Point)

8.2 DPCH reception scheme

The receiver structure (in the UE) to support FB Mode Transmit Diversity operation for DPCH is shown in Figure 7. The additional functionality in the UE to support FB mode transmit diversity consists of the following sub-functions:

- channel estimation from Primary CCPCH pilots
  - the channel estimates are used for determination of antenna weight factors, and optionally for antenna verification and DPCH detection
- transmitter antenna weight computation
  - determination of weight factors
- antenna verification
  - antenna verification may be used to recover from cases where the transmit antenna differs from that designated by uplink signaling command; this sub-function is used in conjunction with transmitter antenna switching.

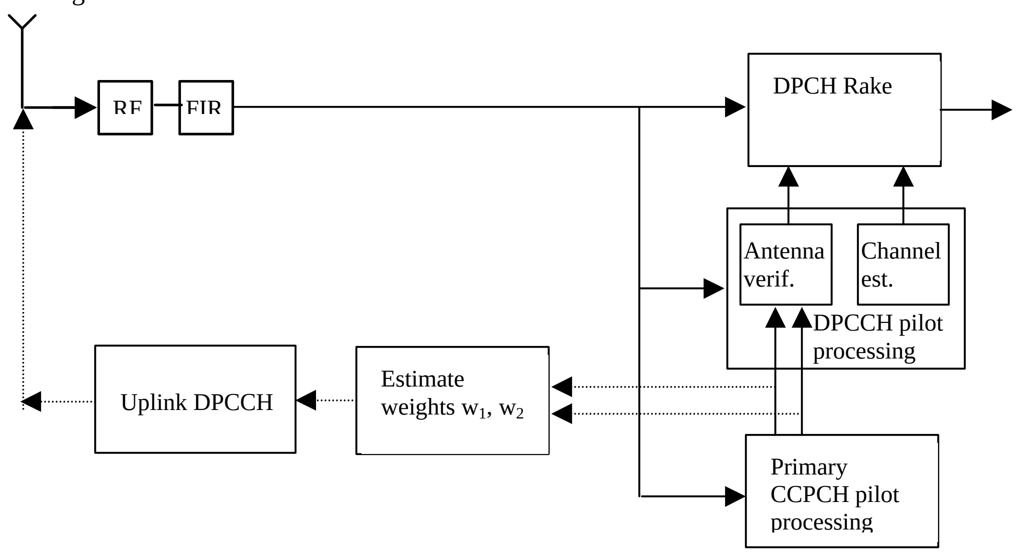

Figure 7: Downlink receiver structure to support FB Mode Transmit Diversity for DPCH transmission (at the UE)

The downlink DPCCH and DPDCH are detected with a standard RAKE receiver in the UE. For FB mode 1 (antenna selection, defined below), the channel estimates can be those obtained from the Primary CCPCH (maybe with antenna verification) in conjunction with the dedicated channel pilots. For FB modes 2 and 3, channel estimates can be those obtained from the dedicated downlink pilots (see Figure 7).

8.3 Use of FB mode

FB mode is used on downlink dedicated channels. FB mode is used when the UE is in non-soft handover mode. Open-loop transmit diversity modes are used during soft handover.
The choice of whether to use FB mode, and the parameters associated with the feedback mode, are both decided by the UTRAN access point. The UE can also request the mode change via higher layer signaling, but the final decision is made by the UTRAN access point.
The transmission diversity mode is designated by sending a higher layer command from the UTRAN access point to the UE.

8.4 Uplink signalling channel

In FB mode, it is recommended that the number of feedback information bits per slot N_{FBI}=1. This represents only a small signalling overhead.
The UE feeds back to the UTRAN access point the information on which phase amplitude/power settings to use (the "weights"). Note that antenna selection corresponds to the case where the weights are taken from the set {0,1}.

8.4.1 FB signalling message

Tentatively three sets of signaling messages are recommended, defining three FB Modes. Let N_W be the number of bits per feedback signaling word on the uplink, giving a feedback update rate of once per N_W/N_{FB} (=N_Slot) slots.

Table 5

FB mode	N_{FB}	N_W	Update rate	Feedback bit rate	N_{ampl_bits}	N_{phase_bits}
1	1	1	1 600 Hz	1 600 bps	1 (table 2)	0
2	1	2	800 Hz	1 600 bps	0	2 (table 3)
3	1	4	400 Hz	1 600 bps	1 (table 4)	3 (table 5)

Mode 1 uses 1-bit words to select antennas with an update rate of 1600 Hz. It is preferred when the UE is moving at moderate or high mobile speed, or whenever there exist limitations to the optimum usage of other feedback modes (e.g. common clock reference cannot be used for both antennas).
Mode 2 uses 2-bit words to adjust phase only with an update rate of 800 Hz. It therefore maintains equal power between the antennas. It is preferred where reduced power amplifier peaking may be exchanged for a slight degradation in performance (when compared to mode 3).
Mode 3 uses 4-bit words to adjust both phase and amplitude with an update rate of 400 Hz. It is preferred when the UE is moving at low speed.
Tables 6 to 9 below give the binary signaling words, together with their interpretation at the transmit array (in terms of relative powers and phases to be applied between the antennas). Note that for the phase information, the sets of signaling words are Gray coded.

Table 6

Value	Power_ant1	Power_ant2
0	0	1
1	1	0

Table 7

Value	Phase_diff
0 0	180
0 1	-90
1 1	0
1 0	90

Table 8

Value	Power_ant1	Power_ant2
0	0.2	0.8
1	0.8	0.2

Table 9

Value	Phase diff
0 0 0	180
0 0 1	-135
0 1 1	-90
0 1 0	-45
1 1 0	0
1 1 1	45
1 0 1	90
1 0 0	135

The `phase_diff` is the phase difference (in degrees) between antenna 1 and antenna 2.
When N_{ampl_bits}=0, equal power is applied to each antenna.
Note that antennas 1 and 2 are uniquely defined by their respective Primary CCPCH pilot codes. Note further that signaling schemes to support more than 2 antennas are *ffs*.
The amplitude and phase applied per antenna is called a "weight", and the set of weights is grouped into a "weight vector". Specifically, the weight vector in the case of 2 antennas is given by:

$$\underline{w} = \begin{bmatrix} \sqrt{power\_ant1} \\ \sqrt{power\_ant2}.\exp(jp.phase\_diff\ /180) \end{bmatrix}.$$

8.5 Determination of feedback information

The UE uses the pilots transmitted on the Primary CCPCH to separately estimate the channels seen from each antenna. Once every N_Slot slot times, the UE computes the phase and amplitude adjustments that should be applied at the UTRAN access point to maximise the UE received power, from within the set of adjustments allowed by the chosen feedback mode defined with tables 1 to 5.
In a generic sense, this is the weight vector $\underline{w}$ that maximises

$$P=\underline{w}^H H^H H\underline{w} \qquad (1)$$

where

$$H=[\underline{h}_1\ \ \underline{h}_2 \ldots]$$

and where the column vector $\underline{h}_i$ represents the estimated channel impulse response for the i'th transmission antenna, of length equal to the length of the channel impulse response.
In practice, the maximisation may be carried out in a number of ways, all of which have a low associated mobile station complexity:
For FB mode 1, a solution to (1) is to simply to select the antenna having the highest received power.
For flat fading, the optimum weight is simply the complex conjugate of the channel. The UE can simply choose the weight vector from the set of weight vectors allowed within the FB mode, which is "closest" to this optimum.
Otherwise, an example of a conceptually simple way to perform this maximisation is to evaluate the equation (1) for each candidate weight vector allowed within the sub-mode. The associated complexity in the mobile station is low, since:

- the number of vectors allowed by the signaling is small (maximum 16);
- the dimensions involved are small, e.g. vectors of dimension-2 for 2 antennas;
- this is only performed once every N_Slot slot times.

8.6 Signalling errors

Errors in the feedback channel cause the UTRAN access point to implement the incorrect phase/amplitude settings. The performance degradation depends on feedback channel error rate and FB mode used. For typical feedback channel error rates (1…4 %), only a slight performance degradation is caused by erroneous feedback channel.
In FB mode 1, if channel estimates are taken from the Primary CCPCH, the performance will also suffer if the UE can not detect errors since the channel estimates will be taken for the incorrect antenna. To mitigate this problem, antenna verification can be done, which can make use of antenna specific pilot patterns of the dedicated physical channel. The antenna verification can be implemented with several different algorithms. As an example if we have different pilot patterns on the downlink DPCCH we can apply coherent antenna verification in which we select antenna with pilot pattern $\mathbf{s}_1$ if the following relation holds,

$$2\,\mathrm{Re}\{\mathbf{w}_1^H\mathbf{y} - \mathbf{w}_2^H\mathbf{y}\} - \|\mathbf{w}_1\|^2 + \|\mathbf{w}_2\|^2 > \hat{s}^2 \ln\frac{P(\mathbf{s}_2)}{P(\mathbf{s}_1)} \qquad (2)$$

where $P(\mathbf{s}_1)$ and $P(\mathbf{s}_2) = 1 - P(\mathbf{s}_1)$ are the *a priori* probabilities for pilot patterns (=transmit antenna) $\mathbf{s}_1$ and $\mathbf{s}_2$, respectively, $\hat{s}^2$ is an estimate of noise power, $\mathbf{w}_i = \left[\hat{a}_{i,1} s_i[0], \cdots, \hat{a}_{i,L} s_i[N-1]\right]^T$, $y_l[i]$ is correlator output for path *l*, and $\hat{a}_{1,l}$ and $\hat{a}_{2,l}$ denote the channel estimates for antennas. In normal operation the *a priori* probability for selected pilot pattern is assumed to be 96% (assuming there are 4% of errors in the feedback channel for power control and antenna selection).

For FB modes 2 to 3, the Gray coding of the uplink signalling information, together with the use of dedicated pilots for the reception of downlink DPCH, is used to minimise the impacts of feedback errors.

History

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