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TECHNICAL REPORT

Digital cellular telecommunications system (Phase 2+) (GSM); Solutions for GSM/EDGE Base Transceiver Station (BTS) energy saving (3GPP TR 45.926 version 16.0.0 Release 16)

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650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
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Contents

Foreword

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Introduction

Energy saving is important for operators' operational efficiency. Energy consumption is a significant operational cost factor, for example in developing markets, up to 30% of OPEX is spent on energy. For one operator group, almost 80% of base stations in Africa and India use diesel as the primary or as a backup power source. Furthermore, base stations account up to 80% of the total CO_2 emissions in a mobile operator network. Many operators have a target to cut CO_2 emissions as part of their environmental objectives. With increasing voice usage, data usage (e.g. introduction of smart phones, MTC devices, etc.) and more dense networks, the thirst for energy consumption is expected to increase further, hence, motivating the need for low energy base station technology. Increasing the energy efficiency of base stations or reducing the energy consumption of base stations will also facilitate the possibility for operators to power all types of base stations with alternative fuels and rely less on fossil fuels either from diesel generators or from the electricity grid.

1 Scope

The present document provides a study into BTS energy saving solutions. The present document analyses and evaluates different solutions to determine the benefits provided compared to the legacy BTS energy consumption.

In the scope of this study there are following solutions:

- Reduction of Power on the BCCH carrier (potentially enabling dynamic adjustment of BCCH power)
- Reduction of power on DL common control channels
- Reduction of power on DL channels in dedicated mode, DTM and packet transfer mode
- Deactivation of cells (e.g. Cell Power Down and Cell DTX like concepts as discussed in RAN [4])
- Deactivation of other RATs in areas with multi-RAT deployments, for example, where the mobile station could assist the network to suspend/minimize specific in-use RATs at specific times of day
- And any other radio interface impacted power reduction solutions

The solutions will also consider the following aspects:

- Impacts on the time for legacy and new mobile stations to gain access to service from the BTS
- Impacts on legacy and new mobile stations to keep the ongoing service (without increasing drop rate)
- Impacts on legacy and new mobile stations implementation and power consumption, e.g. due to reduction in DL power, cell (re-)selection performance, handover performance, etc.
- Impacts on UL/DL coverage balance, especially to CS voice

Solutions will be considered for both BTS energy saving non-supporting and supporting mobile stations (i.e. solutions that are non-backwards compatible towards legacy mobile stations will be out of the scope of this study).

The contents of the present document when stable will determine the modifications to existing GERAN specifications.

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. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] 3GPP TR 41.001: "GSM Release specifications".

[3] ETSI TS 102 706: "Energy Efficiency of Wireless Access Network Equipment".

[4] 3GPP TR 25.927: "Solutions for Energy Savings within UTRA NodeB", V.10.0.0

[5] 3GPP TS 45.002: "Multiplexing and multiple access on the radio path".

[6] 3GPP TS 45.008: "Radio subsystem link control".

[7] 3GPP TR 45.913: "Optimized transmit pulse shape for downlink Enhanced General Packet Radio Service (EGPRS2-B)".

[8] 3GPP TR 45.050: "Background for Radio Frequency (RF) requirements".

[9] 3GPP TR 45.914: "Circuit switched voice capacity evolution for GSM/EDGE Radio Access Network (GERAN)".

[10] 3GPP TS 24.008: "Mobile radio interface Layer 3 specification; Core network protocols; Stage 3".

[11] 3GPP TR 45.912: "Feasibility study for evolved GSM/EDGE Radio Access Network (GERAN)".

[12] 3GPP TS 44.018: "Mobile radio interface layer 3 specification; Radio Resource Control (RRC) protocol".

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in TR 21.905 [1].

busy hour: one hour period during which occurs the maximum total load in a given 24-hour period

busy hour load: average BTS load during busy hour

energy efficiency: relation between the useful output and energy/power consumption

low load: average BTS load during time when there is only very low traffic in network

medium term load: defined BTS load level between busy hour and low load levels

3.2 Symbols

Void.

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1].

AFS	Adaptive multirate Fullrate Speech
AHS	Adaptive multirate Halfrate Speech
APD	Average Power Decrease
BBU	Base Band Unit
BHT	Busy Hour Traffic
BTS	Base Transceiver Station
DARP	Downlink Advanced Receiver Performance
EGPRS	Enhanced General Packet Radio Service
EGPRS2	Enhanced General Packet Radio Service phase 2
FTP	File Transfer Protocol
GoS	Grade of Service
IRC	Interference Rejection Combining
LA	Link Adaptation
MCBTS	Multi-Carrier BTS
MCPA	Multi-Carrier Power Amplifier
NC1	Network Control mode 1
RE	Radio Equipment
SAIC	Single Antenna Interference Cancellation
SCPA	Single Carrier Power Amplifier
TRX	Transceiver
VAMOS	Voice services over Adaptive Multi-user channels on One Slot

4 Study Considerations

4.0 General

This clause depicts considerations on appropriate network scenarios and on qualitative analysis of the BTS energy consumption.

4.1 Network Scenario Considerations

All the scenarios to be studied in BTS energy saving are listed in this subclause. The scenarios should consider deployment, GERAN configuration (e.g. CS+PS resource dimensioning, EGPRS, EGPRS2), cell utilization, etc.

Below is a list of aspects that could be used to characterize the energy saving scenarios:

- Deployment and coverage:
  - GERAN only, multi cell, single band, 900 coverage layer
  - GERAN only, multi cell, single band, 1800 capacity layer
  - GERAN only, multi cell, dual band with 900 coverage layer, 1800 capacity layer
- BTS type and configuration:
  - Number of sectors and carriers
  - SCPA (Normal BTS) and MCPA (MCBTS)
- The following traffic and load models are assumed:
  - SDCCH configuration model
  - Traffic load profiles for low load, medium term load and busy hour load subscriber traffic (derived from ETSI TS 102 706 [3], Annex D)
- Backward compatibility to previous MS releases

4.2 Energy Consumption of BTS

This clause contains a qualitative analysis of energy consumption breakdown of current BTSs for different antenna/carrier configurations, topologies and DL and UL loading scenarios.

The components listed below are the main parts in a BTS energy consumption breakdown, containing BBU, REs, power supply, coaxial feed, and other related consumptions. The relation in Table 4.2-1 is summarized based on a variety of configurations of BTSs under a low load assumption specified as 10% in ETSI TS 102 706 [3].

Table 4.2-1: Power Consumption breakdown of a BTS

BTS component	Qualitative contribution to Total Power Consumption of BTS
Base Band Unit (BBU)	Medium
Radio Equipments (RE)	High
Primary DC Power Supply (i.e. rectifiers, battery)	Medium
Coaxial feed pressurization/dehydration	Medium (vary with feeder length and diameter)
Other related consumption(like fan, lighting, alarm, etc.)	Low (under typical environmental conditions)

From Table 4.2-1, the BTS component RE appears to contribute the most to the total BTS power consumption. However, the qualitative analysis above does not take into consideration the different permutations of BTS type and configuration, which can influence alternative energy saving solutions and is an important aspect in the definitions of the scenarios.

5 Objectives

This clause describes how to evaluate the solutions and the rules for adopting energy saving solution into the present document. To this purpose performance and compatibility objectives are defined. For each objective an evaluation metric will be defined for benchmarking the proposed candidate solutions. A candidate solution will not be necessarily discarded, if it does not fulfil a particular objective, but this will be taken into account in the overall evaluation of the candidate solution and in the comparison against other candidate solutions.

5.1 Performance Objectives: energy efficiency target

The energy efficiency will be measured in terms of relative energy savings in % versus a reference configuration, where the reference configuration does not apply any energy saving mechanism and is based on the configuration specified in subclause 6.1 and based on the agreed minimum GoS requirements as stated in subclause 5.2.1 and 5.2.2 and the fulfillment of the requirement stated in subclause 5.2.3. The relative energy savings are to be evaluated in regard to TRX power consumption and in regard to average RF output power as stated in subclause 6.6.2.

5.2 Compatibility Objectives

There are seven compatibility objectives defined for this study.

5.2.1 Avoid impact to voice user call quality

The introduction of a candidate solution will minimize degradation of voice quality as perceived by the user. The acceptable limit for the call blocking rate is less than 2%. For the candidate solution the call quality will fulfil the target of at least 95% of satisfied users, where the call FER, determined as average FER over the entire call duration, will be less than 2% for FR codecs and less than 3% for HR codecs. The percentage of satisfied users will be recorded for the reference case and the candidate solution.

5.2.2 Avoid impact to data user session quality

The introduction of a candidate solution will minimize degradation of active data sessions for the user. The degradation of the session throughput will be recorded at the 10th, 50th and 90th percentiles of the session throughput cumulative distribution function.

5.2.3 Avoid impact to cell (re)selection and handover

Impact to cell (re)selection and handover should be minimized with any candidate solution, in that additional cell reselections and handovers compared to the reference case will be minimized. The call drop rate will not be higher than 0.2% for the reference case and the candidate solution. If the reference case does not meet this call drop rate level, the call drop rate of the candidate solution will not be worse compared to the reference case.

5.2.4 Support of legacy MSs

Legacy MS types will be supported.

5.2.5 Implementation impacts to new MSs

The introduction of any candidate solution proposed under this study should avoid changes to MS hardware. Additional complexity in terms of processing power and memory should be kept to a minimum for a new MS. Impacts to power consumption should be avoided.

5.2.6 Implementation impacts to BSS

The introduction of any candidate solution proposed under this study should change BSS hardware as little as possible and HW upgrades to the BSS should be avoided.

5.2.7 Impacts to network planning

Impacts to network planning and frequency reuse will be avoided.

6 Common Assumptions

This clause lists the common assumptions for the evaluation of candidate solutions.

6.1 Reference Configuration

The reference configuration described hereafter is derived from that specified in Annex D, Table D.1 of ETSI TS 102 706 [3].

Table 6.1-1 below describes the load conditions for various load levels and site configurations. The BCCH TRX is active in every site configuration and for different load levels. The busy hour traffic figures for the three site configurations listed in the rightmost column are taken from Table 6.3-1.

Table 6.1-1: Load model for different site configuration and offered load level

	Low load	Medium term load	Busy hour load
Load for S222	- BCCH TRX: all TS except TS0 can be allocated for user traffic - Other TRX: all TS allowed for user traffic - Mean Traffic load per sector: 20% of busy hour (see Table 6.3-1)	- BCCH TRX: all TS except TS0 can be allocated for user traffic - Other TRX: all TS allowed for user traffic - Mean Traffic load per sector: 50% of busy hour (see Table 6.3-1)	- BCCH TRX: all TS except TS0 can be allocated for user traffic - Other TRX: all TS allowed for user traffic - Mean traffic load per sector: according to busy hour (see Table 6.3-1)
Load for S444	- BCCH TRX: all TS except TS0 can be allocated for user traffic - Other TRX: all TS allowed for user traffic - Mean Traffic load per sector: 20% of busy hour (see Table 6.3-1)	- BCCH TRX: all TS except TS0 can be allocated for user traffic - Other TRX: all TS allowed for user traffic - Mean Traffic load per sector: 50% of busy hour (see Table 6.3-1)	- BCCH TRX: all TS except TS0 can be allocated for user traffic - Other TRX: all TS allowed for user traffic - Mean traffic load per sector: according to busy hour (see Table 6.3-1)
Load for S888 (optional)	- BCCH TRX: all TS except TS0 can be allocated for user traffic - Other TRX: all TS allowed for user traffic - Mean Traffic load per sector: 20% of busy hour (see Table 6.3-1)	- BCCH TRX: all TS except TS0 can be allocated for user traffic - Other TRX: all TS per each sector can be allocated and remaining TS idle - Mean traffic load per sector: 50% of busy hour (see Table 6.3-1)	- BCCH TRX: all TS except TS0 can be allocated for user traffic - Other TRX: all TS allowed for user traffic - Mean traffic load per sector: according to busy hour (see Table 6.3-1)
Load level duration	6 hours	10 hours	8 hours

The evaluation will be performed for configurations S222 and S444 and optionally for configuration S888, since configurations S222 and S444 are considered sufficient to prove gains in BTS energy saving. Dedicated signalling channels (SDCCH) are modelled for each cell according to Table 6.1-2. The load model for these channels (i.e. channel usage for call set-up phase, location signalling, etc.), the allocation of these channels (i.e. if allocated on BCCH TRX and/or on any other TRX belonging to the cell) and the energy saving method for these channels (i.e. applied power reduction/power control method) need to be reported.

Table 6.1-2: Number of SDCCH channels per sector for each site configuration and each load profile

Site Configuration	Load Profile 1 Low Traffic Load (20% of BHT) with 100 % FR codec	Load Profile 2 Medium Term Traffic Load (50% of BHT) with	Load Profile 3 High Traffic Load (100% of BHT) with 100% FR codec	Load Profile 4 High Traffic Load (100% of BHT) with 100% HR codec

		100 % FR codec		**(optional)**
S222	1	1	1	2
S444	2	2	2	4
S888 (optional)	4	4	4	8

The evaluation will be performed for load profiles 1 to 3, whilst load profile 4 is optional, since load profiles 1 to 3 are considered sufficient to prove gains in BTS energy saving. Reference deployment scenarios are listed in subclause 6.4.

6.2 Evaluation Metrics

Appropriate metrics for the evaluation by means of dynamic system simulations need to be identified.

Two Radio Equipment (RE) related performance metrics for energy efficiency evaluation are defined as reflected in the performance objective in clause 5.1:

- RE Performance Metric 1: Gain in Cumulated TRX power consumption for all TRXs belonging to a cell.
- RE Performance Metric 2: Gain in Average RF output power for all TRXs belonging to a cell.

For comparison of candidate techniques RE Performance Metric 1 has higher priority than RE Performance Metric 2.

The evaluation should refer to energy savings in percent versus the reference configuration specified in subclause 6.1. The method for evaluating the performance gain is further described in subclause 6.6.2.

NOTE: Dynamic system simulations can be supported by measurements from real networks.

6.3 Traffic Load profiles

The busy hour traffic for the three site configurations from Table 6.1-1 are detailed in Table 6.3-1. CS voice traffic is 0,020 Erlangs/subscriber during Busy Hour. CCCH is allocated on one timeslot.

Table 6.3-1: Load profiles for different site configuration

Site Configuration	Load Profile 1 Low Traffic Load (20% of BHT) with 100 % FR codec	Load Profile 2 Medium Term Traffic Load (50% of BHT) with 100 % FR codec	Load Profile 3 High Traffic Load (100% of BHT) with 100% FR codec	Load Profile 4 High Traffic Load (100% of BHT) with 100% HR codec (optional)
S222	4,8 Erlangs (3×1,6)	12,3 Erlangs (3×4,1)	24,6 Erlangs (3×8,2)	54,9 Erlangs (3×18,3)
S444	12,6 Erlangs (3×4,2)	31,5 Erlangs (3×10,5)	63,0 Erlangs (3×21,0)	131,7 Erlangs (3×43,9)
S888 (optional)	26,1 Erlangs (3×8,7)	73,2 Erlangs (3×24,4)	146,1 Erlangs (3×48,7)	292,8 Erlangs (3×97,6)

The traffic load levels in Table 6.3-1 are derived from a call blocking rate of 2% assumed for the busy hour traffic in load profile 3 and load profile 4 and from the indicated share of the busy hour load of load profile 3 in case of load profile 1 and load profile 2. Table 6.3-1 is valid for the voice-only scenario.

For the mixed voice/data scenario the traffic load levels need to be modified to accommodate the traffic on data channels. A straightforward way is to use the same traffic load levels as for the voice only scenario depicted in Table 6.3-1 and reuse the call arrival model. For each call arrival it will be decided with a probability of 70% that a voice call is requested and with a probability of 30% that a data session is requested according to the entry in Table 6.4-1. Note for each data user a session has a size of 800 kb according to the data traffic model in Table 6.4-1. If this session was transported over only 1 TS with an average throughput of only 10 kBit/s, then the session would have a duration of 80 s, which is less than the assumed mean call duration of 90 s for a voice call. Hence the overall traffic load for the mixed voice/data scenario is assumed to not exceed the one for the voice only scenario. The traffic load for the data sessions for load profile 4 is derived from load profile 3 in that it is equal.

BCCH time slot allocation for both traffic scenarios related to voice and data traffic is depicted in Table 6.4-1.

6.4 Reference deployment scenarios

Further detailing of deployment scenarios listed in clause 4.1 is of importance to progress evaluations on identified candidate solutions.

Following settings are proposed for network parameters as depicted in Table 6.4-1 below.

Table 6.4-1: Network parameters for site configurations defined in subclause 6.1

Parameter	Value	Unit	Comment
Sectors per site	3		
Frequency Band	900 / 1800	MHz	
Cell size	2000 500	m m	Coverage layer (900 MHz) as investigated in TR 45.050 Annex Z.B.2.3 for MCBTS Capacity layer (1800 MHz) as investigated in 3GPP TR 45.913 and 45.914
BCCH frequency re-use	4/12		BCCH frequency reuse applied also in WIDER, see 3GPP TR 45.913, and MUROS, see 3GPP TR 45.914, feasibility studies.
BCCH TS occupation	TN 0 **Traffic scenario 1** (Voice only): TN 1…7 **Traffic scenario 2** (Mixed voice/data scenario): for low load / medium term load: TS occupation for voice and data flexible for busy hour load: voice: TN 5...7 data: TN 1...4		BCCH/CCCH, multiple CCCH not used. TS for TCH in the voice only scenario excluding TS on BCCH carrier allocated to SDCCH. TS for TCH in the mixed voice / data scenario excluding TS on BCCH carrier allocated to SDCCH. The SDCCH allocation needs to be described for the candidate technique (see subclause 6.1).
TCH frequency re-use	Configuration 2/2/2: 1/1 and 3/9 for RF synthesizer hopping 3/9 for baseband hopping Configuration 4/4/4: 1/1 and 3/9 for RF synthesizer hopping 3/9 for baseband hopping Configuration 8/8/8 (optional): 1/1 and 3/9 for RF synthesizer hopping 3/9 for baseband hopping		TCH frequency reuse figures depend on the site configuration under investigation and the frequency hopping type. Site configurations are according to subclause 6.1 . For baseband hopping the BCCH carrier is included in the hopping set. Information on the frequency hopping type, on MA length, on MAIO allocation and on how the imposed bandwidth restriction for hopping carriers is taken into account in the modelling should be reported.
Frequency Allocation Site configuration 2/2/2 Site configuration 4/4/4 Site configuration 8/8/8 (optional)	 21 frequencies (12 + 9) 39 frequencies (12 + 27) 75 frequencies (12 + 63)		 BCCH frequencies and TCH frequencies separated by 1 guard frequency (0.2 MHz)
Bandwidth of BCCH layer	2.4 MHz		
Bandwidth of TCH layer Site configuration 2/2/2 Site configuration 4/4/4 Site configuration 8/8/8 (optional)	 1.8 MHz 5.4 MHz 12.6 MHz		 TCH on adjacent freq. TCH on adjacent freq. TCH on adjacent freq.
Path loss model	Okumura-Hata		ETSI TS 102 706 - rural (cell size 2000 m) - urban (cell size 500 m) A description on modelling short distances should be provided.
Log-normal fading st.dev	6	dB	ETSI TS 102 706
Correlation distance	110	m	

Parameter	Value	Unit	Comment
Inter-site log-normal correlation coefficient	50	%	
Handover margin	3	dB	
BTS output power for BCCH carrier and other carriers	43	dBm	Other output power levels may in addition be used in the study but need to be indicated.
BTS antenna height	40	m	ETSI TS 102 706
BTS Sector antenna pattern	65º deg H-plane, max TX gain 18	dBi	UMTS 30.03 (modified from assumption in ETSI TS 102 706)
BTS feeder and connector loss	3	dB	ETSI TS 102 706
BTS sensitivity BTS noise figure		dBm dB	implementation dependent implementation dependent
MS output power	31 (GSM 900) 28 (DCS 1800)	dBm	ETSI TS 102 706
RACH power reduction	Disabled		
MS antenna height	1,5	m	ETSI TS 102 706
MS antenna gain	0	dBm	ETSI TS 102 706
MS sensitivity MS noise figure	-104 8	dBm dB	ETSI TS 102 706
Body loss	3	dB	ETSI TS 102 706
Indoor/Outdoor users	0 / 100	%	Outdoor users are more interesting in a reselection/handover study. This will effectively eliminate the impact of building penetration loss listed in ETSI TS 102 706
Traffic scenarios Traffic scenario 1 Traffic scenario 2	 100 % voice users 70 % voice users, 30 % data users		 First priority for evaluation Second priority for evaluation Note VAMOS channels are not included for voice.
Average power decrease (APD) for voice	0,2,..,APDmax	dB	Level chosen according to power control.
Average power decrease (APD) for data	GMSK: 0 dB 8PSK: 4.0 dB 16QAM: 6.0 dB 32QAM: 6.0 dB (Values from 3GPP TS 45.008)		
Average power decrease (APD) for dummy bursts	APDmax	dB	Pre-CCCH timeslot has APDmax = 3 dB.
Speech codecs	FR: AFS 12.2 and AFS 5.9 HR: AHS 5.9 and GSM HR		FR codecs are evaluated at all traffic load levels. HR codecs are only evaluated at busy hour traffic load level and are optional (load profile 4).
DARP phase I penetration rate	Traffic scenario 1: 60% Traffic scenario 2: 60% for voice users, 100% for data users		See clause 6.5.8.
AMR codec mode adaptation	Disabled		
DTX on DL/UL	Enabled		
Channel allocation strategy	Description of channel allocation strategy		Information should be provided (e.g. allocation priority for channel on BCCH layer / TCH layer and other criteria).

Parameter	Value	Unit	Comment
Handover	Penalty in terms of speech frame erasures during handover to be taken into account for DL and UL.		Vendor specific penalty. Aligned to MUROS TR 45.913 Information on enabling of intra-cell handovers and on HO penalty size for inter-/ intra-cell handovers should be provided.
DL Repeated FACCH	Optional		assumed to be supported by legacy MS Enabling/disabling should be reported.
Repeated SACCH	Disabled		not supported by legacy MS
Voice call model	- Poisson distributed call arrivals and exponential call durations. - mean call duration: 90 sec - min. call duration: 5 sec.		Aligned to MUROS TR 45.913
Data traffic model	- PS data transfer size per session: 100 kB - MCS belonging to GPRS and EGPRS to be used in phase 1 of the study. MCS for EGPRS2 to be used in phase 2 of the study.		In WIDER TR 45.913 FTP service with 1 MB file size has been assumed. In GERAN Evolution TR 45.912 FTP service with 100 and 120 kB was assumed aside HTTP traffic.
Link adaptation	Enabled		LA kept vendor specific
Fading channel profile	Typical Urban (TU)		
Paging cycle	BS_PA_MFRMS = 4 (4*235.38 ms = 941.5 ms)		relevant for MS measurements in idle mode.
Number of cells in neighbour cell list	12		relevant for measurements in idle and connected mode
Number of reported neighbour cells	6		signalled in normal measurement reporting
Reselection criteria	C2 = C1		Represents the default case in TS 45.008, i.e. no additional parameters for cell reselection are broadcast
MS velocity	3 km/h and 50 km/h		3 km/h evaluated for all scenarios 50 km/h only evaluated for certain scenarios, see subclause 6.5.7

A high level description of the user mobility model should be provided. Information in regard to the traffic load creation and handling of service area border effects may be beneficial to be reported. Other simulation parameters such as simulated time, network size, usage of propagation wrap around need to be reported.

6.5 MS characteristics

The need for clarification of MS related procedures has been raised during the study in order to create a simplistic model for measurement sampling, averaging and cell reselection procedures and handover preparation in the MS. These items are subject for discussion with MS manufacturers and feedback was requested to derive such a model. Behaviour of legacy MS in field and new MS has to be distinguished. Deviations from the common assumptions stated in this clause need to be reported.

6.5.1 BCCH carrier power measurement sampling

6.5.1.1 Idle mode

In idle mode, information was provided during Telco#1 on BTSEnergy, that the measurement window of the MS for monitoring signal strength of serving cell and neighbour cells is enlarged compared to connected mode, but it is sufficiently different from selecting a time slot on random basis between 0 and 7. Measurements in idle mode are not taken in a continuous manner, since the MS will enter DRX periods and only measure during active periods between two DRX periods. Feedback received from MS manufacturers so far indicates that all BCCH measurements, performed for serving cell and neighbour cells, are done in the time interval where the MS listens to its paging block.

The minimum performance requirement for cell selection in idle mode is specified in TS 45.008 in subclause 6.6.1:

Whilst in idle mode an MS will continue to monitor all BCCH carriers as indicated by the BCCH allocation (BA - See table 1). A running average of received signal level (RLA_C) in the preceding 5 to:

$$\text{Max} \{5 , ((5 * N + 6) \text{ DIV } 7) * \text{BS\_PA\_MFRMS} / 4\}$$

seconds will be maintained for each carrier in the BCCH allocation. N is the number of non-serving cell BCCH carriers in BA and the parameter BS_PA_MFRMS is defined in 3GPP TS 45.002.

The same number of measurement samples will be taken for all non-serving cell BCCH carriers of the BA list, and the samples allocated to each carrier will as far as possible be uniformly distributed over each evaluation period. At least 5 received signal level measurement samples are required per RLA_C value. New sets of RLA_C values will be calculated as often as possible.

Hence at least 5 samples need to be taken in a period no shorter than 5 seconds for all neighbour cells (i.e. Max {5 , ((5 * N + 6) DIV 7) * BS_PA_MFRMS / 4}). Consequently the number of neighbour cells N is an important parameter to define the length of the averaging period. The meaning of the above formula in TS 45.008 is an important clue to help identify mobiles behaviour. Figure 6.5-1 below shows an example for neighbour cell monitoring in idle mode.

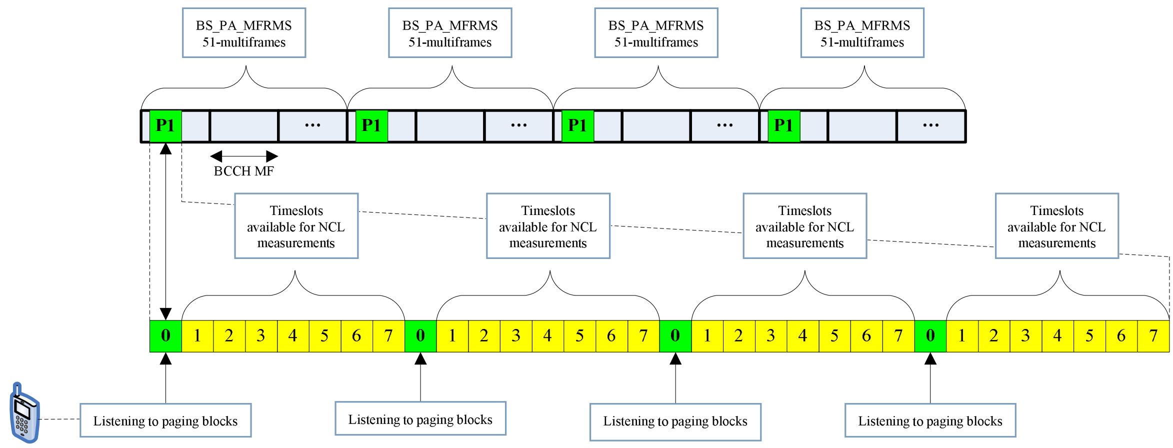

Figure 6.5-1 Example for MS neighbour cell monitoring in idle mode.

The MS belonging to P1 paging group needs to monitor downlink CCCH for paging. During reading paging messages there are totally 28(7*4) idle slots for mobiles to monitor neighbour cells (7 timeslots in each frame). The time for each neighbour cell measurement is consisted of the monitoring time for measurements and the switching time between two neighbour BCCH frequencies. To guarantee the time for measurements is sufficiently long it can be assumed that during this period totally 7 samples are made for neighbour cells (i.e. the sampling is made every 4 timeslots). Suppose for each neighbour cell 5 samples are made then the total number of paging blocks which completes the measurement for all neighbour cells reach to (5 * N + 6) DIV 7). Since the period for each paging group equals to 240 ms* BS_PA_MFRMS (≈BS_PA_MFRMS/4), the total time for samples averaging approximately equals to ((5 * N + 6) DIV 7) * BS_PA_MFRMS / 4.

From the above analysis it can be assumed that when 5 samples are required for each neighbour cell and sampling is made every 4 timeslots (7 samples are collected in each paging reading), the averaging time reaches to ((5 * N + 6) DIV 7) * BS_PA_MFRMS / 4.

It is thus necessary to define typical values for the mentioned parameters including BS_PA_MFRMS, number of neighbour cells and number of samples to be taken into account in the performance evaluations. At GERAN#50 agreement was found on following parameters in Table 6.5-1.

Table 6.5-1: Parameters for MS measurements in idle mode

Parameters	Value
Number of neighbour cells	12
BS_PA_MFRMS	4
Number of samples per neighbour cell for cell (re)selection	5

Based on these figures, the minimum requirement as depicted in TS 45.008 related to cell (re)selection can be derived. In addition measurement patterns for neighbour cells in idle mode can be derived based on the assumption that sampling is made every 4 timeslots in the non-DRX mode as depicted above.

6.5.1.2 Connected mode

In connected mode it is assumed that the MS performs only 1 neighbour cell BCCH power measurement per TDMA frame. This would be rather on the same time slot (e.g. on time slot preceding DL receive timeslot or any other suitable time slot). Note this assumption is expected to apply for a multislot supporting mobile, that has a bidirectional data transfer ongoing, such as class 12 (4+1) and higher. Also for a MS handling voice service, it is expected that one time slot per TDMA frame is available for sampling the received power of one neighbour cell.

6.5.2 BCCH carrier power measurement accuracy

A sufficient large measurement sampling window of 64 symbols for idle and connected mode at MS side is assumed, yielding a margin of ±1 dB for the tolerances in regard to difference between power measurements as confirmed by feedback of MS manufacturers. This figure is valid for a non-fading channel only. The impact of the fading radio channel has to be superposed on top of this level of accuracy.

6.5.3 BCCH carrier power measurement averaging

The MS behaviour related to averaging of neighbour cell measurements in idle mode is described in subclause 6.5.1.1.

In the connected mode, TS 45.008, subclause 7.2, specifies that comparison of averaged power measurements for neighbour cells will be based on the time period of 2 SACCH block periods, in order to derive the need for BSIC detection. Feedback received from MS manufacturers indicates that averaging of serving cell and neighbour cell measurements is done per SACCH period. This means that 100 TDMA frames are available if 4 search frames are used for BSIC decoding and other measurement tasks. With the assumption stated in subclause 6.5.1 above that 1 neighbour cell BCCH can be measured per TDMA frame, which is assumed to be valid both for legacy MS with voice calls or multislot MS as depicted in subclause 6.5.1 above, and that the complete BA list is processed, the number of measurements per neighbour cell for averaging then solely is dependent on the length of the neighbour cell list N, i.e. N_av = int (100 / N). For the agreed value of N = 12 (see table 6.5-1), the number of neighbour cell measurement samples per SACCH period equals 8.

6.5.4 BSIC Decoding

The identification of suitable cells, i.e. the serving cell in case of idle mode and neighbour cells in case of connected mode, is subject to successful BSIC decoding, once the neighbour cell has sufficient signal strength. For instance TS 45.008, subclause 6.6.1 describes the BSIC decoding requirement for idle mode:

- The MS will attempt to check the BSIC for each of the 6 strongest non-serving cell BCCH carriers at least every 30 seconds, to confirm that it is monitoring the same cell.

Further TS 45.008 subclause 7.2 specifies the BSIC decoding requirement in dedicated mode:

- If, after averaging measurement results over 2 SACCH block periods, the MS detects one or more BCCH carriers, among the 6 strongest, whose BSICs are not currently being assessed, then the MS will as a matter of priority attempt to decode their BSICs.

Modelling of the BSIC decoding process in idle and in connected mode, such as defining a minimum radio channel quality for successful BSIC decoding, was discussed during Telco#2. Feedback received from MS manufacturers indicates that the overall impact of BSIC decoding is seen as low since the process is much less executed than the frequent BCCH power measurements and a decoding failure is unlikely to result in a cell (re)selection failure or a handover failure. Thus no modelling of the BCCH decoding process is mandated for this study. However for taking into account impact of neighbour cell quality during preparation phase for handover and cell (re-)selection it may be useful to be modelled.

6.5.5 Power reduction on TS preceding BCCH timeslot

No further power reduction on the timeslot preceding the BCCH or CCCH timeslot is foreseen in comparison to what is allowed in TS 45.008 subclause 7.1 in regard to modulations other than GMSK:

- Furthermore, between a slot used for BCCH/CCCH and the slot preceding it, the difference in output power actually transmitted by the BTS will not exceed 3 dB.

This includes output power tolerance on BTS transmitter side.

6.5.6 Handover, Cell Selection and Cell Reselection

The impact on cell selection and cell reselection performance will be evaluated for each candidate solution against the reference case. The number of cell reselections and handovers will be counted for the reference case and the candidate solution in the evaluation period. The call drop rate will be evaluated in all cases. The method to derive the call drop rate and the handover failure rate need to be reported. For handover a penalty in terms of speech frame erasures needs to be taken into account as described in Table 6.4-1. For cell (re-)selection NC1 mode is assumed.

6.5.7 Mobile velocity

Mobile velocity of 3 km/h will be considered for all scenarios.

Mobile velocity of 50 km/h will be considered for low and medium traffic load profiles, i.e. load profiles 1 and 2 in subclause 6.3, for both selected full rate speech codecs, i.e. AFS 12.2 and AFS 5.9. In addition high traffic load profiles, i.e. load profiles 3 and 4 in subclause 6.3, may be investigated.

The mobility model used in the performance evaluation will be described for each candidate solution.

6.5.8 Mobile station types

The MS types used in the evaluation need to be specified. A distinction is done between traffic scenario 1 (voice only) and traffic scenario 2 (mix of voice and data).

Traffic scenario 1: all MS are single TS mobiles (MSC=1) with DARP phase I penetration rate of 60%.

Traffic scenario 2: MS with voice service: single TS (MSC=1) with DARP phase I penetration rate of 60%,

MS with data service: MSC=12 with DARP Phase I penetration rate of 100%.

6.6 BTS characteristics

6.6.1 Network synchronization

The study will investigate both synchronized networks and asynchronous networks.

For intra-site synchronization TDMA frame alignment is assumed in both cases.

For inter-site synchronization time slot alignment is assumed on random basis with fixed offsets in case of synchronized networks, whilst neither TDMA frame alignment nor multi-TDMA frame alignment is part of this assumption.

For inter-site synchronization no time slot or frame alignment (multi-frame, TDMA frame, time slot) is assumed in case of asynchronous networks.

6.6.2 Modelling of TRX power consumption

Modeling of TRX power consumption aspects is needed in order to accurately model expected savings in BTS power consumption. Typically the power consumption of a SCPA TRX is not linear, i.e. a 3 dB decrease in RF output power does not correspond to a 50% decrease of TRX power consumption. Also ramping down of a SCPA TRX may yield to higher energy savings than taken into account in savings for the RF output power. This is similar for a BTS with MCPA component. To take any non-linear dependency between RF output power and actual TRX power consumption into account two metrics to quantify the relative power savings during the performance evaluation are introduced based on the definitions in clause 6.2:

- RE Performance Metric 1: relative energy savings in % related to the reference configuration
- RE Performance Metric 2: relative energy savings in % related to the reference configuration

Both metrics refer to the comparison of the candidate solution against the reference configuration depicted in subclause 6.1 and will be related to the BTS power consumption including BCCH TRX and non-BCCH TRX, or in case of MCPA including total number of operated BCCH and TCH carriers.

7 Candidate Solution: BCCH Carrier Power Reduction Methodology

7.1 Introduction

This methodology is proposed to involve a dynamic power adjustment scheme to each timeslot on BCCH carrier by traffic load.

7.2 Methodology

The methodology is applied to GMSK modulated BCCH carrier. Two variants have been included. The value of X should be pre-set.

7.2.1 Variant 1

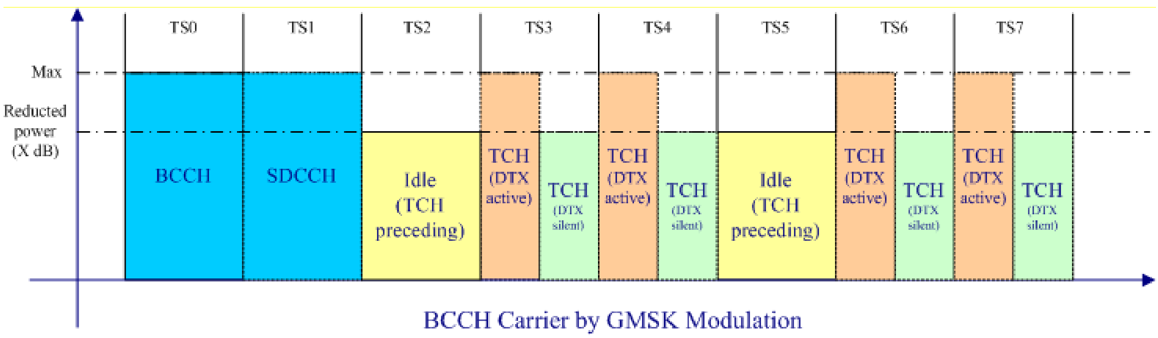

Figure 7.2-1: BCCH Carrier Power Reduction Method; Variant 1

- The timeslots used as control channel (TS0, TS1, blue area) is transmitted with maximum power.
- For idle TCH timeslots (yellow area), the BCCH carrier is transmitted with X dB power reduction.
- During DTX active period (orange area) of TCH timeslots, the BCCH carrier is transmitted with maximum power.
- During DTX silence period (green area) of TCH timeslots, the BCCH carrier is transmitted with X dB power reduction.

Table 7.2-1: Power Scheme of Variant 1

Timeslot Preceding	Traffic Status	DTX status	BCCH Carrier Transmit Power
BCCH/SDCCH	Idle	N/A	Maximum
BCCH/SDCCH	Busy	N/A	Maximum
TCH	Idle	N/A	Reduced by X dB
TCH	Busy	Active period	Maximum
TCH	Busy	Silence period	Reduced by X dB

7.2.2 Variant 2

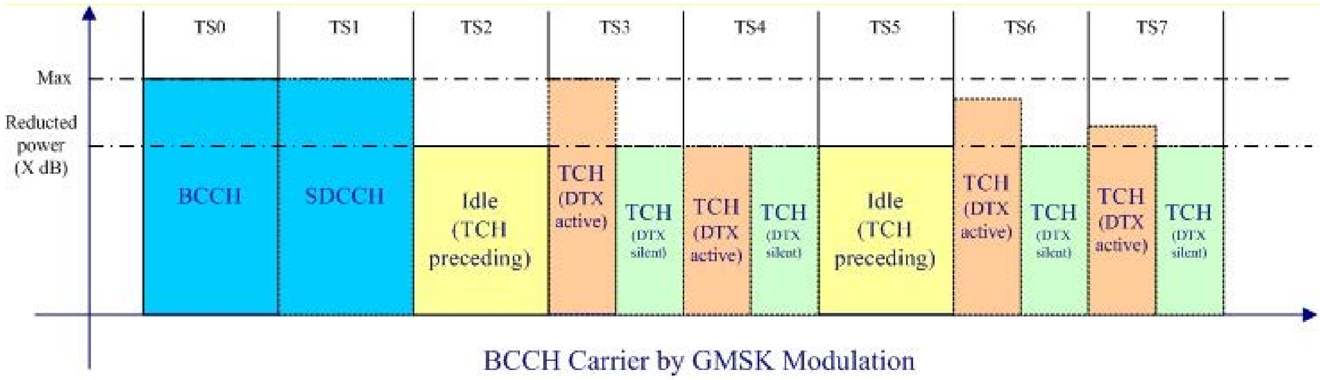

Figure 7.2-2: BCCH Carrier Power Reduction Method; Variant 2

- The timeslots used as control channel (TS0, TS1, blue area) is transmitted with maximum power.
- For idle TCH timeslots (yellow area), the BCCH carrier is transmitted with X dB power reduction.
- During DTX active period (orange area) of TCH timeslots, power control algorithm is applied to BCCH carrier, but the total reduced power is not allowed to exceed X dB.
- During DTX silence period (green area) of TCH timeslots, the BCCH carrier is transmitted with X dB power reduction.

Table 7.2-2: Power Scheme of Variant 2

Timeslot Preceding	Traffic Status	DTX status	BCCH Carrier Transmit Power
BCCH/SDCCH	Idle	N/A	Maximum
BCCH/SDCCH	Busy	N/A	Maximum
TCH	Idle	N/A	Reduced by X dB
TCH	Busy	Active period	Power control applied (reduction not exceed X dB)
TCH	Busy	Silence period	Reduced by X dB

7.3 Evaluation

Three cases are simulated to compare:

Reference case: No BCCH power reduction is applied.

Case 1: Variant 1 is applied, with x = 2;

Case 2: Variant 2 is applied, with x = 2;

Assumptions are aligned to current common assumptions.

7.3.1 Simulation Assumptions

Table 7.3-1: Simulation Assumptions

Parameter	Default Value	Unit
Frequency band	900	MHz
BCCH frequency re-use	4/12	-
TCH frequency re-use	1/1 3/9	
Frequency Hopping	1/1 for synthesizer hopping 3/9 for baseband hopping	-
Cell Size	500	m
Network size	84 cells	
Sectors (cells) per Site	3	-
Sector Antenna Pattern	UMTS 30.03	-
Propagation Model	Okumura-Hata	dB
Log-Normal Fading: Standard Deviation	6	dB
Log-Normal Fading: Correlation Distance	110	m
Log-Normal Fading: Inter-Site Correlation	50	%
Adjacent Channel Interference Attenuation	18	dB
Fast Fading	Enabled	
Fast Fading Type	TU3	km/hr
Receiver Type	Conventional Receiver(DL EGC/ UL IRC)	
SAIC penetration rate	60	%
Speech codec	AFS 12.2	
Traffic mix	100 % voice	
Indoor/outdoor users	0/100	%

Table 7.3-2: Traffic Load Configuration

	Low load	Medium load	Busy hour load
Load for 222	- BCCH TRX: all TS except TS0 can be allocated for user traffic - Other TRX: all TS allowed for user traffic - Mean Traffic load per sector: 20% of busy hour	- BCCH TRX: all TS except TS0 can be allocated for user traffic - Other TRX: all TS allowed for user traffic - Mean Traffic load per sector: 50% of busy hour	- BCCH TRX: all TS except TS0 can be allocated for user traffic - Other TRX: all TS allowed for user traffic - Mean traffic load per sector: according to busy hour
Load for 444	- BCCH TRX: all TS except TS0 can be allocated for user traffic - Other TRX: all TS allowed for user traffic - Mean Traffic load per sector: 20% of busy hour	- BCCH TRX: all TS except TS0 can be allocated for user traffic - Other TRX: all TS allowed for user traffic - Mean Traffic load per sector: 50% of busy hour	- BCCH TRX: all TS except TS0 can be allocated for user traffic - Other TRX: all TS allowed for user traffic - Mean traffic load per sector: according to busy hour
Load for 888	BCCH TRX: all TS except TS0 can be allocated for user traffic Other TRX: all TS allowed for user traffic - Mean Traffic load per sector: 20% of busy hour	- BCCH TRX: all TS except TS0 can be allocated for user traffic - Other TRX: all TS per each sector can be allocated and remaining TS idle - Mean traffic load per sector: 50% of busy hour	- BCCH TRX: all TS except TS0 can be allocated for user traffic - Other TRX: all TS allowed for user traffic - Mean traffic load per sector: according to busy hour

Table 7.3-3: Load profiles for different site configuration

Site Configuration	Load Profile 1 Low Traffic Load (20% of BHT) with 100 % FR codec	Load Profile 2 Medium Traffic Load (50% of BHT) with 100 % FR codec	Load Profile 3 High Traffic Load (100% of BHT) with 100% FR codec	Load Profile 4 High Traffic Load (100% of BHT) with 100% HR codec
S222	4,8 Erlangs (3×1,6)	12,3 Erlangs (3×4,1)	24,6 Erlangs (3×8,2)	54,9 Erlangs (3×18,3)
S444	12,6 Erlangs (3×4,2)	31,5 Erlangs (3×10,5)	63,0 Erlangs (3×21,0)	131,7 Erlangs (3×43,9)
S888	26,1 Erlangs (3×8,7)	73,2 Erlangs (3×24,4)	146,1 Erlangs (3×48,7)	292,8 Erlangs (3×97,6)

Table 7.3-4: Number of SDCCH channels per sector for each site configuration and each load profile

Site Configuration	Load Profile 1 Low Traffic Load (20% of BHT) with 100 % FR codec	Load Profile 2 Medium Traffic Load (50% of BHT) with 100 % FR codec	Load Profile 3 High Traffic Load (100% of BHT) with 100% FR codec	Load Profile 4 High Traffic Load (100% of BHT) with 100% HR codec
S222	1	1	1	2
S444	2	2	2	4
S888	4	4	4	8

7.3.2 Evaluations

7.3.2.1 Impacts to Radiated Power and Power Consumption

Table 7.3-5: Average Tx power on the BCCH carrier

TCH Frequency Reuse	Site Configuration	Traffic Load	Reference Case (dBm)	Case 1 (dBm)	Case 2 (dBm)
1/1 Reuse	S222	Busy Hour	43	42.21	41.71
		Medium	43	42.06	41.7
		Low	43	41.85	41.7
	S444	Busy Hour	43	42.32	41.93
		Medium	43	42.29	41.93
		Low	43	42.16	41.91
	S888	Busy Hour	43	42.5	42.35
		Medium	43	42.49	42.35
		Low	43	42.48	42.35
3/9 Reuse	S222	Busy Hour	43	42.18	41.7
		Medium	43	42	41.7
		Low	43	41.84	41.7
	S444	Busy Hour	43	42.3	41.92
		Medium	43	42.28	41.92
		Low	43	42.14	41.91
	S888	Busy Hour	43	42.5	42.35
		Medium	43	42.48	42.35
		Low	43	42.47	42.35

The simulation results in table 7.3-5 show the average Tx power, evaluated only for the BCCH carrier, which is not compliant with the common assumptions in clause 6.2 of providing accumulated average Tx power over all carriers, however, the observed reduction in Tx power on BCCH carrier proves the feasibility of this candidate technique at certain extent.

Table 7.3-6: Average power consumption on the BCCH carrier

TCH Frequency Reuse	Site Configuration	Traffic Load	Reference Case (Watt)	Case 1 Relative Decrease (%)	Case 2 Relative Decrease (%)
1/1 Reuse	S222	Busy Hour	240	8.33	12.5
		Medium	240	8.75	12.5
		Low	240	10	12.5
	S444	Busy Hour	240	5.83	10
		Medium	240	6.25	10
		Low	240	8.75	10
	S888	Busy Hour	240	4.58	5.83
		Medium	240	4.58	5.83
		Low	240	4.58	5.83
3/9 Reuse	S222	Busy Hour	240	8.75	12.5
		Medium	240	9.17	12.5
		Low	240	11.67	12.5
	S444	Busy Hour	240	6.25	10
		Medium	240	6.67	10
		Low	240	8.75	10
	S888	Busy Hour	240	4.58	5.83
		Medium	240	4.58	5.83
		Low	240	4.58	5.83

The simulation results in table 7.3-6 show decreased power consumption, evaluated only for the BCCH carrier, which is not compliant with the common assumptions in clause 6.2 of providing accumulated TRX power consumption over all carriers. However, the observed decreased power consumption on BCCH carrier proves the feasibility of this candidate technique at certain extent.

7.3.2.2 Impacts to Call Quality

The following table includes the percentage of satisfied users (FER ≤ 2%) for different load scenarios and site configurations.

Table 7.3-7 Percentage of satisfied users

TCH Frequency Reuse	Site Configuration	Uplink or Downlink	Traffic Load	Reference Case (100%)	Case 1 (100%)	Case 2 (100%)
1/1 Reuse	S222	UL	Busy Hour	99.57	98.71	97.86
			Medium	98.29	97.44	97.44
			Low	99.9	98.8	98
		DL	Busy Hour	99.15	99.14	98.71
			Medium	99.15	99.15	99.15
			Low	99.7	99.5	99.3
	S444	UL	Busy Hour	97.78	94.85	94.27
			Medium	98.75	98.75	97.18
			Low	98.39	97.58	96.77
		DL	Busy Hour	96.67	94.85	94.58
			Medium	98.75	98.75	97.5
			Low	99.42	99.23	99.19
	S888	UL	Busy Hour	94.72	93.69	93.42
			Medium	98.06	97.93	96.84
			Low	98.58	98.23	97.52
		DL	Busy Hour	93.37	92.52	91.93
			Medium	97.69	96.96	96.84
			Low	98.58	97.86	97.51
3/9 Reuse	S222	UL	Busy Hour	97.83	97.79	97.69
			Medium	99.74	99.49	99.23
			Low	99.9	98.72	98.08
		DL	Busy Hour	96.48	96.34	95.97
			Medium	99.23	98.97	98.46
			Low	99.36	98.08	96.15
	S444	UL	Busy Hour	96.71	96.51	96.49
			Medium	98.72	98.33	98.13
			Low	98.39	98.39	98.12
		DL	Busy Hour	96.09	95.37	94.9
			Medium	97.74	97.64	97.64
			Low	98.93	98.66	98.4
	S888	UL	Busy Hour	95.49	95.2	95.16
			Medium	98.18	98.05	97.89
			Low	99.53	99.3	98.94
		DL	Busy Hour	94.37	94.25	94.17
			Medium	97.72	97.43	96.64
			Low	98.83	98.83	98.59

From the evaluation results, the BCCH power reduction method decreases the percentage of satisfied users. However, in most cases, this KPI still fulfills the 95% target or within 2% degradation compare to reference case. During the busy hours, the power reduction method does not perform well in S444 configuration, 1/1 reuse.

7.3.2.3 Impacts to Handover

HO modeling: Use the link FER to determine whether SABM and UA frames are successfully delivered. If the SABM and UA frames fail to be sent/received after retry, a HO failure is marked.

Call drop modeling: 1. HO failure may leads to a call drop; 2. Use the link FER to determine whether SACCH frame is correctly transmitted. The threshold for call drop depends on how many SACCH frame fails within an interval.

HO Penalty: Penalty in terms of speech frame erasures during handover to be taken into account for DL and UL. Aligned to MUROS TR 45.913.

Table 7.3-8: Handover number

TCH Frequency Reuse	Site Configuration	Traffic Load	Reference Case	Case 1	Case 2
1/1 Reuse	S222	Busy Hour	188	185	183
		Medium	70	63	60
		Low	45	40	40
	S444	Busy Hour	1030	948	758
		Medium	250	245	230
		Low	78	75	75
	S888	Busy Hour	2795	2750	2723
		Medium	883	825	790
		Low	195	193	178
3/9 Reuse	S222	Busy Hour	685	628	610
		Medium	240	233	223
		Low	105	85	85
	S444	Busy Hour	2323	2280	2178
		Medium	840	788	780
		Low	260	235	230
	S888	Busy Hour	6033	5965	5870
		Medium	2200	2190	2153
		Low	608	603	598

From the evaluation results, the total number of handover slightly decreases after power reduction method had been applied.

Table 7.3-9: Call Drop Rate

TCH Frequency Reuse	Site Configuration	Traffic Load	Reference Case (100%)	Case 1 (100%)	Case 2 (100%)
1/1 Reuse	S222	Busy Hour	0.03	0.05	0.09
		Medium	0.02	0.03	0.05
		Low	0	0	0
	S444	Busy Hour	0.05	0.07	0.11
		Medium	0.03	0.05	0.08
		Low	0	0	0
	S888	Busy Hour	0.09	0.13	0.20
		Medium	0.05	0.08	0.11
		Low	0.05	0.07	0.10
3/9 Reuse	S222	Busy Hour	0.02	0.03	0.05
		Medium	0.01	0.02	0.04
		Low	0	0	0
	S444	Busy Hour	0.04	0.07	0.09
		Medium	0.02	0.05	0.06
		Low	0	0.01	0.01
	S888	Busy Hour	0.07	0.11	0.15
		Medium	0.01	0.04	0.05
		Low	0	0.02	0.05

The call drop rate slightly increased while all cases are within the 0.2% target.

7.4 Conclusion

This candidate technique has impacts to network KPI. The total handover number slightly decreases when it is applied. The percentage of satisfied users may decrease but be within a 95% target in most cases, especially when the reference case meets the target. It also has limited impacts to the call drop rate. It was observed that the investigated power reduction for the BCCH carrier is up to 12.5 % for the small site configuration S(2/2/2) and up to 10 % for the medium site configuration S(4/4/4), respectively. It is noted that the evaluation was not in alignment with the common assumptions in clause 6.2 requiring the evaluation of the cumulated TRX power consumption over all carriers of the base station. Thus the observed gains can be seen rather as indicative for a possible significant power saving.

8 Candidate Solution: Output Power Reduction on BCCH Carrier for GMSK

8.1 Introduction

The need to investigate energy savings in the GERAN networks and in particular at the BTS side has been previously raised in GERAN [8-1]. This clause depicts the candidate technique 'output power reduction on BCCH carrier for GMSK'. It is judged to achieve significant energy savings in networks in low and medium loaded network scenarios. After the concept description performance evaluation results for various defined scenarios are reported that confirm the assumption that this candidate technique will lead to significant OPEX savings.

8.2 Concept Description

This clause depicts the concept of the output power reduction on BCCH carrier for GMSK candidate technique.

8.2.1 Overview

Energy saving in the BTS may be possible across the whole network for times with low and medium traffic loads, e.g. at night when there is no or very few traffic served on the BCCH transceiver or during other day phases with medium traffic. In these times a reduced output power could be permitted on the BCCH carrier for all time slots carrying GMSK modulation except time slots carrying BCCH and CCCH channels as well as timeslots preceding them. The latter ones are excluded due to impact on BCCH monitoring task in the mobile.

In addition power reduction on specific time slots on the BCCH carrier, allocated to SDCCH/8 channels, which are used by multiple mobile stations and only sporadically, such as for location update, during channel access or for directed retry, is excluded, since the power reduction estimate may be unreliable due to insufficient channel quality measurements.

In case of absence of traffic channels, i.e. presence of idle time slots, TS 45.008 specifies that dummy bursts have to be sent using GMSK modulation at maximum Tx power on the BCCH carrier. Also for GMSK modulated traffic channels the usage of maximum TX power on the BCCH carrier is currently specified.

The proposed concept foresees to operate all time slots on BCCH carrier using GMSK modulation, except the time slot carrying the BCCH/CCCH or further BCCH/CCCH channels (in case of extended BCCH or multiple CCCH configurations) and SDCCH/8 channels, with a modified output power, as follows:

- a static maximum output power reduction of APDmax = 2, 4 or 6 dB for idle time slots on BCCH carrier.

- a dynamic output power reduction of APDdyn = m * 2 dB , with m steps, up to the maximum power reduction APDmax for time slots carrying TCH on BCCH carrier. Time slots dedicated to TCH handling distant users with high pathloss will use maximum output power, whilst users with lower pathloss will be served with reduced output power.

- a static output power reduction of APDmax,red = 2 dB for TN 7 and in addition for all time slots preceding CCCH timeslots in case of Multiple CCCH.

The applied power reduction of 2 dB equals one power step. On other TRX than the BCCH TRX normal dynamic transmit power control is applied.

8.2.2 Exemplary Scenario

The different power levels for one TDMA frame are depicted in Figure 8.2-1 for one exemplary scenario with 1 SDCCH on TN 1 and three active TCH users, one with high, another with medium and another with low pathloss.

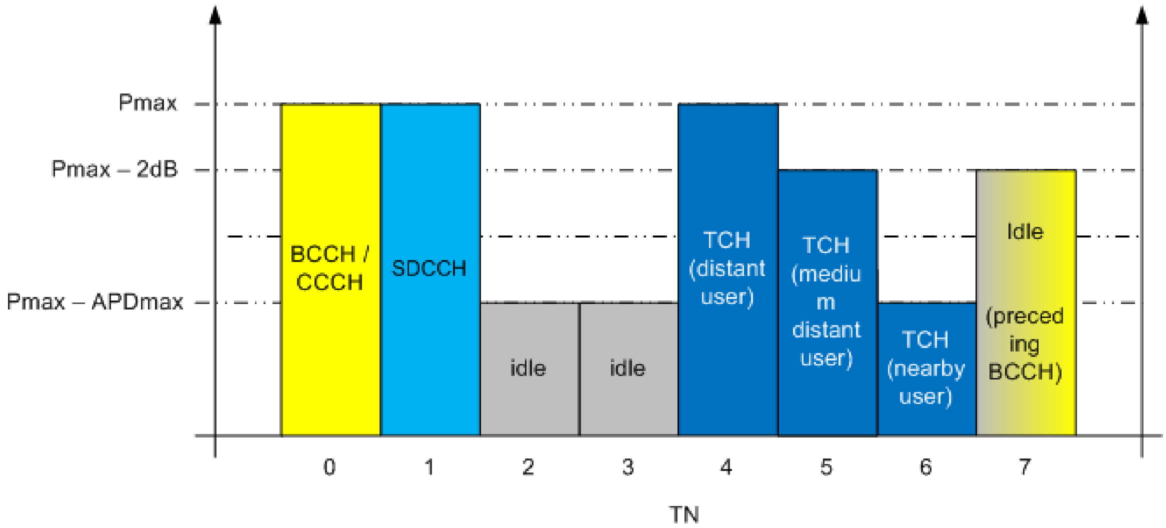

Figure 8.2-1: Output power reduction on BCCH carrier for selected GMSK modulated timeslots using static and dynamic power reduction in 2 dB power steps

8.3 Concept Evaluation

8.3.0 Overview

This clause depicts simulation results from the evaluation of the BCCH power saving method introduced in [8-2] and described above. Clause 8.3.1 provides an overview of the simulation model and of the applied power reduction method, clause 8.3.2 describes the observed performance for eight specific scenarios. The specification impact is analysed in clause 8.3.3. The conclusion and further proceeding are outlined in clause 8.4.

8.3.1 Simulation Model

The simulation model is described hereafter including general simulation assumptions, investigated channel allocation strategies, evaluated deployment scenarios, the network layout, the output power reduction settings on BCCH carrier and the employed Link-to-System Mapping.

8.3.1.1 Simulation Assumptions

The general simulation assumptions are summarized in Table 8.3-1.

Table 8.3-1: Summary of simulation assumptions.

Parameter	Value	Unit	Comment
Sectors per site	3		
Frequency Band	900 1800	MHz	
Cell size	2000 500	m	Coverage layer (900 MHz, rural) Capacity layer (1800 MHz, urban)
BCCH frequency re-use	4/12		
TS occupation on BCCH carrier	**Traffic scenario 1** (Voice only): S(2/2/2): TN 2…7 S(4/4/4): TN 3…7		BCCH allocation: on TN 0. SDCCH allocation: S(2/2/2): TN 1 of BCCH TRX, operated without power reduction. S(4/4/4): TN 1, TN 2 of BCCH TRX, operated without power reduction. TCH allocation: all TS of cell excluding TS on BCCH carrier allocated to BCCH / SDCCH.
TCH frequency re-use	S(2/2/2): 1/1 for RF synthesizer hopping S(4/4/4): 1/1 for RF synthesizer hopping		S(2/2/2): MA length is 9 for hopping channel. Bandwitdth restriction is taken into account by loss factor of 3 dB against ideal frequency hopping. Coherence BW for paths in rural area between 2 and 4 km is up to 1 MHz [8-3]. S(4/4/4): MA length is 27 for hopping channel. Bandwitdth restriction is taken into account by loss factor of 0 dB against ideal frequency hopping.
Frequency Allocation	S(2/2/2): 21 frequencies (total) 12 (BCCH layer) 9 (TCH layer) S(4/4/4): 39 frequencies (total) 12 (BCCH layer) 27 (TCH layer)		BCCH frequencies and TCH frequencies separated by 1 guard frequency (0.2 MHz)
Bandwidth of BCCH layer	2.4 MHz		
Bandwidth of TCH layer	S(2/2/2): 1.8 MHz S(4/4/4): 5.4 MHz		TCH layer in one frequency block
Path loss model	Okumura-Hata		ETSI TS 102 706 - rural (cell size 2000 m) - urban (cell size 500 m) Short distances are modelled by means of a two breakpoint model with LOS area, LOS-NLOS transition area and NLOS area aligned to ITU-R F1336-4 and ECC Report 146. MCL = 59 dB is applied acc. to 3GPP 45.050 for GSM900 small cells.
Log-normal fading st.dev	6	dB	ETSI TS 102 706
Correlation distance	110	m	
Inter-site log-normal correlation coefficient	50	%	
Handover margin	3	dB	
BTS output power for BCCH carrier and other carriers	43	dBm	
BTS antenna height	40	m	ETSI TS 102 706
BTS Sector antenna pattern	65º deg H-plane, max TX gain 18	dBi	UMTS 30.03 (modified from assumption in ETSI TS 102 706)
BTS feeder and connector loss	3	dB	ETSI TS 102 706

Parameter	Value	Unit	Comment
BTS sensitivity BTS noise figure		dBm dB	implementation dependent implementation dependent
MS output power	31 (GSM 900) 28 (DCS 1800)	dBm	ETSI TS 102 706
RACH power reduction	Disabled		
MS antenna height	1.5	m	ETSI TS 102 706
MS antenna gain	0	dBm	ETSI TS 102 706
MS sensitivity MS noise figure	-104 8	dBm dB	ETSI TS 102 706
Body loss	3	dB	ETSI TS 102 706
Indoor/Outdoor users	0 / 100	%	Outdoor users are more interesting in a reselection/handover study. This will effectively eliminate the impact of building penetration loss listed in ETSI TS 102 706
Traffic scenarios Traffic scenario 1	 100 % voice users		 First priority for evaluation
Average power decrease (APD) for voice	0 dB up to X dB in 2 dB steps		Level chosen according to dynamic power control. See clause 8.3.1.4
Average power decrease (APD) for dummy bursts	X:= 0 dB, 2 dB, 4 dB, 6 dB		See clause 8.3.1.4
Speech codecs	FR: AFS 12.2		
DARP phase I penetration rate	As defined for traffic scenario 1: 60 %		
AMR codec mode adaptation	Disabled		
DTX on DL/UL	Enabled		
Channel allocation strategy	Description of channel allocation strategy		See clause 8.3.1.2
Handover	Penalty in terms of speech frame erasures during handover to be taken into account for DL and UL.		No intra-cell handovers enabled. HO penalty size of 6 speech frames assumed for inter-cell handovers in case of voice activity.
Handover failure	modelled		Loss of HO command in source cell and failure of HO access in target cell taken into account. Leading to call drop.
Voice call model	- Poisson distributed call arrivals and exponential call durations. - mean call duration: 90 sec - min. call duration: 5 sec.		Aligned to MUROS TR 45.913
Fading channel profile	Typical Urban (TU)		
Paging cycle	BS_PA_MFRMS = 4 (4*235.38 ms = 941.5 ms)		
Number of cells in neighbour cell list	12		
MS velocity	3 km/h		
User mobility model	random movement		User moves in random direction.
Traffic load creation	according to configured load		Traffic is generated at a randomly determined location in a cell after random determination of a cell in the network.
Handling of service area border effects	taken into account in idle and connected mode.		User is moved to a location at the opposite side of the service area with similar propagation conditions to continue the call until its end.

Parameter	Value	Unit	Comment
BSIC decoding	enabled for neighbour cells in idle and connected mode		rate of 9.6 sec in connected mode (for each neighbour cell) and rate of 4.7 sec in idle mode (for each of the strongest 6 neighbour cells).
Propagation wrap around	activated		
Network size	Cluster of 16 sites (48 cells)		Cluster is repeated for propagation wrap around, cell statistic over 48 cells
Network synchronization mode	Timeslot synchronous		TDMA frame synchronous for BS at same cell site, not TDMA frame synchronous for BS of different cell sites
Interference types	Co-channel and 1st adjacent channel		ACP = 18 dB
RLF Timeout	16		Leading to call drop
DL Repeated FACCH	disabled		
Repeated SACCH	disabled		
Simulated time	90 000 TDMA frames 75 000 TDMA frames		Equals about 415 sec (3 km/h) Equals about 346 sec (50 km/h)
Simulated directions	DL and UL		

8.3.1.2 Channel Allocation Strategies

Two different simple channel allocation strategies have been investigated depicted in Table 8.3-2.

Table 8.3-2 Investigated channel allocation strategies

Aspect	Strategy 1	Strategy 2	Strategy 3
Carrier selection	no preference for allocation on BCCH carrier or hopping TCH carrier	preference for channel allocation is given to BCCH carrier	preference for channel allocation is given to BCCH carrier, if the uplink received power on RACH is higher than a pre-defined threshold, else allocated with preference on hopping TCH carrier
TS selection	random selection of time slot, both on BCCH carrier or hopping TCH carrier	random selection of time slot, both on BCCH carrier or hopping TCH carrier	random selection of time slot, both on BCCH carrier or hopping TCH carrier
Activation of non-BCCH TRX	second TRX goes into standby mode once no channel is allocated	second TRX is only activated if the BCCH TRX is filled	second TRX goes into standby mode once no channel is allocated

8.3.1.3 Deployment Scenarios and Network Layout

The following deployment scenarios were evaluated.

Table 8.3-3: Evaluated scenarios for small site configuration S(2/2/2)

Scenario	Frequency band and propagation	Load Profile	Channel Allocation Strategy
S1	GSM 900 rural	Load Profile 1 (20% of BHT) MS velocity: 3 km/h	1
S2	GSM 900 rural	Load Profile 1 (20% of BHT) MS velocity: 3 km/h	2
S3	GSM 900 rural	Load Profile 2 (50% of BHT) MS velocity: 3 km/h	1
S4	GSM 900 rural	Load Profile 2 (100% of BHT) MS velocity: 3 km/h	1
S5	GSM 900 rural	Load Profile 1 (20% of BHT) MS velocity: 50 km/h	3
S6	GSM 900 rural	Load Profile 2 (100% of BHT) MS velocity: 50 km/h	3

Table 8.3-4: Evaluated scenarios for medium site configuration S(4/4/4)

Scenario	Frequency band and propagation	Load Profile	Channel Allocation Strategy
M1	GSM 900 rural	Load Profile 1 (20% of BHT) MS velocity: 3 km/h	2
M2	DCS 1800 urban	Load Profile 1 (20% of BHT) MS velocity: 3 km/h	2

The layout of the simulated network deployment is shown in Figure 8.3-1.

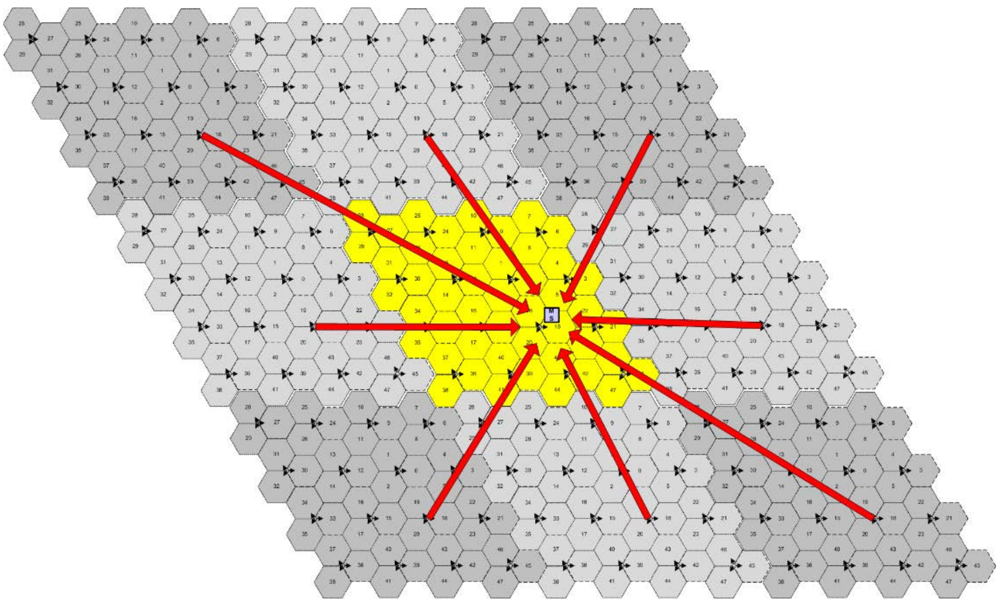

Figure 8.3-1: Layout of simulated network deployment for evaluation of BCCH power reduction. Cell statistic area (yellow) and propagation wrap-around shown for one DL co-channel interferer set (red)

8.3.1.4 Output Power Reduction Settings on BCCH carrier

This clause lists the power reduction settings on BCCH carrier which were evaluated.

For idle timeslots on BCCH carrier, different levels of power reduction were evaluated: 0 dB (reference case), 2 dB, 4 dB and 6 dB. An exception is the timeslot preceding the BCCH; a power reduction of 0 dB (reference case) or 2 dB (power reduction case) was applied in this case.

For the timeslots carrying the SDCCH no power reduction was applied.

For TCH channels, a power reduction of 0 dB up to the configured figure X for idle channels was applied in 2 dB steps according to dynamic power control.

The considered reference case depicts the case of no power reduction on BCCH carrier, whilst dynamic power control is active on hopping TCH layer.

In the evaluation following power reduction settings were thus compared:

- no power reduction on BCCH carrier for idle time slots / TCH time slots (0 dB / 0 dB), reference case;
- a fixed reduction of X dB on BCCH carrier for idle timeslots and a maximum reduction of X dB for TCH time slots (X dB / X dB) with 2 dB steps on TCH time slots and with X = 2, 4, 6. The actual reduction is determined by dynamic power control.

8.3.1.5 Employed Link-to-System Mapping

This clause contains a brief description of the implemented link-to-system mapping in the network simulator used for the evaluation in clause 3.2. It consists of a two stage mapping model including burst level mapping and block level mapping.

For deriving the input to the burst level mapping, received carrier and interferer power levels are determined on burst basis based on coupling loss, addition of shadow fading and rayleigh fading. On BCCH layer correlated rayleigh fading is used due to no frequency hopping and low MS speed of 3 km/h, whilst on TCH layer employing frequency hopping uncorrelated rayleigh fading is added.

For a non SAIC MS, carrier to noise plus interference ratio C/(I+N) is then calculated as input to the burst level mapping, which picks a value of the raw BER distribution.

For a SAIC MS, carrier to noise plus strongest interferer ratio $C/(I_1+N)$ and Dominant to Rest of Interference ratio (DIR) are determined as input to the burst level mapping, which picks a value of the raw BER distribution.

In the block level mapping the accumulated raw BER over 8 bursts is mapped onto the FER, which is derived according to the used codec AFS 12.2.

A user is included in the satisfied user rate, if the call is successfully terminated or if the call needs to be cut and has reached a minimum duration of 30 s.

8.3.2 Simulation Results

This clause presents the simulation results for depicted scenarios in clause 8.3.1.3.

8.3.2.1 Scenario S1

Call quality metrics are shown in table 8.3-5a for DL and UL, where separate statistics for DL are recorded for traffic channels on BCCH layer and TCH layer.

Table 8.3-5a: Call quality metrics

Power reduction on idle TS / TS_{TCH}	Satisfied users DL TCH	Satisfied users DL BCCH	Satisfied users UL TCH	Call block rate	Call drop rate	Handover Failure Rate	Handover rate vs. reference
0 dB / 0 dB	100 %	99.3 %	99.6 %	0 %	0.26 %	0.11 %	-
2 dB / 2 dB	100 %	100 %	100 %	0.24 %	0.59 %	0.29 %	-7.2 %
4 dB / 4 dB	100 %	99.4 %	100 %	0.51 %	0.28 %	0.15 %	-17.0 %
6 dB / 6 dB	99.4 %	100 %	100 %	0 %	0.29 %	0.18 %	-26.5 %

Power consumption metrics in terms of reduction in cumulative output power and reduction in overall TRX power consumption per cell are shown in table 8.3-5b for this scenario.

Table 8.3-5b: Power consumption metrics

Power reduction on idle TS / TS_{TCH}	Mean cumulated output power per cell [dBm]	Reduction of cumulated output power per cell [dB]	Reduction of TRX power consumption per cell
0 dB / 0 dB	43.2	-	-
2 dB / 2 dB	42.0	1.2	7.1 %
4 dB / 4 dB	41.1	2.1	11.6 %
6 dB / 6 dB	40.4	2.8	15.7 %

Observations:

- Satisfied user rates: the required level of 95 % is met in all cases, the actual levels being between 99 % and 100%.
- Call block rate: remains far below 2%. It includes blocking both due to capacity and due to insufficient radio quality.
- Handover failure rate: Handover failures are observed for the reference and all three power reduction settings.
- Call drop rate: Handover failures impact the call drop rate which is still in the order of the required level of 0.2 % except for the setting (2 dB/2 dB).
- Handover rate: is significantly reduced along the level of power reduction. A reduction of up to 26.5 % is achieved.
- Cumulated TRX power consumption: reduction is observed to go up to about 15.7 %.

8.3.2.2 Scenario S2

Call quality metrics are shown in table 8.3-6a for DL and UL, where separate statistics for DL are recorded for traffic channels on BCCH layer and TCH layer.

Table 8.3-6a: Call quality metrics

Power reduction on idle TS / TS_{TCH}	Satisfied users DL TCH	Satisfied users DL BCCH	Satisfied users UL TCH	Call block rate	Call drop rate	Handover Failure Rate	Handover rate vs. reference
0 dB / 0 dB	-	99.1 %	100 %	0.29 %	0.27 %	0.24 %	-
2 dB / 2 dB	-	99.0 %	99.7 %	0 %	0.3 %	0.33 %	-21.0 %
4 dB / 4 dB	-	98.5 %	100 %	0.54 %	0 %	0 %	-26.2 %
6 dB / 6 dB	-	99.1 %	100 %	0 %	0 %	0 %	-26.7 %

Power consumption metrics in terms of reduction in cumulative output power and reduction in overall TRX power consumption per cell are shown in table 8.3-6b for this scenario.

Table 8.3-6b: Power consumption metrics

Power reduction on idle TS / TS_{TCH}	Mean cumulated output power per cell [dBm]	Reduction of cumulated output power per cell [dB]	Reduction of TRX power consumption per cell
0 dB / 0 dB	43.0	-	-
2 dB / 2 dB	41.7	1.3	7.6 %
4 dB / 4 dB	40.8	2.2	12.0 %
6 dB / 6 dB	40.2	2.8	15.7 %

Observations:

- Satisfied user rates: the required level of 95 % is met in all cases, the actual levels being between 98.5 % and 100%. With the applied channel allocation strategy 2 the TCH layer is not loaded in this scenario.
- Call block rate: remains far below 2%. It includes blocking both due to capacity and due to insufficient radio quality.
- Handover failure rate: Handover failures are observed in rare cases for two power reduction settings.
- Call drop rate: Handover failures impact the call drop rate which is still in the order of the required level of 0.2%.
- Handover rate: is significantly reduced along the level of power reduction. A reduction of up to 26.7 % is achieved.
- Cumulated TRX power consumption: reduction is observed to go up to about 15.7 %. The reference case for scenario S2 has a cumulative TRX power consumption of 6.3 % less compared against the reference case of scenario S1.

8.3.2.3 Scenario S3

Call quality metrics are shown in table 8.3-7a for DL and UL, where separate statistics for DL are recorded for traffic channels on BCCH layer and TCH layer.

Table 8.3-7a: Call quality metrics

Power reduction on idle TS / TS_{TCH}	Satisfied users DL TCH	Satisfied users DL BCCH	Satisfied users UL TCH	Call block rate	Call drop rate	Handover Failure Rate	Handover rate vs. reference
0 dB / 0 dB	98.9 %	100 %	99.9 %	0.21 %	0.22 %	0.15 %	-
2 dB / 2 dB	99.5 %	99.7 %	100 %	0.21 %	0 %	0 %	-19.2 %
4 dB / 4 dB	99.3 %	99.7 %	100 %	0.22 %	0.11 %	0.09 %	-20.6 %
6 dB / 6 dB	99.2 %	99.5 %	100 %	0.23 %	0.12 %	0.11 %	-27.3 %

Power consumption metrics in terms of reduction in cumulative output power and reduction in overall TRX power consumption per cell are shown in table 8.3-7b for this scenario.

Table 8.3-7b: Power consumption metrics

Power reduction on idle TS / TS_{TCH}	Mean cumulated output power per cell [dBm]	Reduction of cumulated output power per cell [dB]	Reduction of TRX power consumption per cell
0 dB / 0 dB	43.7	-	-
2 dB / 2 dB	42.6	1.1	6.8 %
4 dB / 4 dB	41.9	1.8	10.5 %
6 dB / 6 dB	41.4	2.3	14.1 %

Observations:

- Satisfied user rates: the required level of 95 % is met in all cases, the actual levels being between 98.9 % and 100%.
- Call block rate: remains far below 2%. It includes blocking both due to capacity and due to insufficient radio quality.
- Handover failure rate: Handover failures are observed in rare cases for three power reduction settings.
- Call drop rate: Handover failures impact the call drop rate which is either below or close to the required level of 0.2 %.
- Handover rate: is significantly reduced along the level of power reduction. A reduction of up to 27.3 % is achieved.
- Cumulated TRX power consumption: reduction is observed to go up to 14.1 %.

8.3.2.4 Scenario S4

Call quality metrics are shown in table 8.3-8a for DL and UL, where separate statistics for DL are recorded for traffic channels on BCCH layer and TCH layer.

Table 8.3-8a: Call quality metrics

Power reduction on idle TS / TS_{TCH}	Satisfied users DL TCH	Satisfied users DL BCCH	Satisfied users UL TCH	Call block rate	Call drop rate	Handover Failure Rate	Handover rate vs. reference
0 dB / 0 dB	96.1 %	98.5 %	99.7 %	0.18 %	0.98 %	0.56 %	-
2 dB / 2 dB	96.7 %	98.7 %	99.8 %	0.21 %	1.0 %	0.71 %	-12.0 %
4 dB / 4 dB	96.7 %	98.5 %	99.8 %	0.06 %	0.92 %	0.63 %	-17.9 %
6 dB / 6 dB	95.5 %	99.3 %	99.8 %	0.06 %	0.67 %	0.74 %	-20.6 %

Power consumption metrics in terms of reduction in cumulative output power and reduction in overall TRX power consumption per cell are shown in table 8.3-8b for this scenario.

Table 8.3-8b: Power consumption metrics

Power reduction on idle TS / TS_{TCH}	Mean cumulated output power per cell [dBm]	Reduction of cumulated output power per cell [dB]	Reduction of TRX power consumption per cell
0 dB / 0 dB	44.2	-	-
2 dB / 2 dB	43.3	0.9	4.9 %
4 dB / 4 dB	42.7	1.5	8.6 %
6 dB / 6 dB	42.3	1.9	11.2 %

Observations:

- Satisfied user rates: the required level of satisfied users of 95 % are met in all cases, the actual levels being between 95.5 % and 99.3 % on downlink and close to 100% on UL.
- Call block rate: remains far below 2%. It includes blocking both due to capacity and due to insufficient radio quality. It decreases along the level of power reduction. This is reasoned by the slightly increased good server cells, see Figures 8.3-2 and 8.3-3.
- Handover failure rate: Handover failures are observed for all settings.
- Call drop rate: Handover failures leading to an increased call drop rate between 0.67 % and 1.0 %, thus exceeding the required level of 0.2 %. However no increase of the call drop rate with regard to the reference is observed.
- Handover rate: is significantly reduced along the level of power reduction. A reduction of up to 20.6 % is achieved.
- Cumulated TRX power consumption: reduction is observed to go up to 11.2 %.

8.3.2.5 Scenario M1

Call quality metrics are shown in table 8.3-9a for DL and UL, where separate statistics for DL are recorded for traffic channels on BCCH layer and TCH layer.

Table 8.3-9a: Call quality metrics

Power reduction on idle TS / TS_{TCH}	Satisfied users DL TCH	Satisfied users DL BCCH	Satisfied users UL TCH	Call block rate	Call drop rate	Handover Failure Rate	Handover rate vs. reference
0 dB / 0 dB	100 %	99.6 %	99.9 %	0.53 %	0.10 %	0.10 %	-
2 dB / 2 dB	100 %	99.9 %	100 %	0.11 %	0 %	0 %	-11.7 %
4 dB / 4 dB	100 %	99.8 %	99.9 %	0.11 %	0 %	0 %	-18.8 %
6 dB / 6 dB	100 %	99.9 %	99.8 %	0 %	0 %	0 %	-22.6 %

Power consumption metrics in terms of reduction in cumulative output power and reduction in overall TRX power consumption per cell are shown in table 8.3-9b for this scenario.

Table 8.3-9b: Power consumption metrics.

Power reduction on idle TS / TS_{TCH}	Mean cumulated output power per cell [dBm]	Reduction of cumulated output power per cell [dB]	Reduction of TRX power consumption per cell
0 dB / 0 dB	43.1	-	-
2 dB / 2 dB	42.2	0.9	4.3 %
4 dB / 4 dB	41.6	1.5	7.0 %
6 dB / 6 dB	41.2	1.9	8.9 %

Observations:

- Satisfied user rates: the required level of 95 % is met in all cases, the actual levels being between 99 % and 100%.
- Call block rate: decreases along the level of power reduction. This is reasoned by the slightly increased good server cells, see Figures 8.3-2 and 8.3-3. In all cases it remains far below 2%. It includes blocking both due to capacity and due to insufficient radio quality.
- Handover failure rate: Handover failures are observed only for the reference case.
- Call drop rate: Handover failures impact the call drop rate which is still below the required level of 0.2 %.
- Handover rate: is significantly reduced along the level of power reduction. A reduction of up to 22.6 % is achieved.
- Cumulated TRX power consumption: reduction is observed to go up to 8.9 %.

8.3.2.6 Scenario M2

Call quality metrics are shown in table 8.3-10a for DL and UL, where separate statistics for DL are recorded for traffic channels on BCCH layer and TCH layer.

Table 8.3-10a: Call quality metrics

Power reduction on idle TS / TS_{TCH}	Satisfied users DL TCH	Satisfied users DL BCCH	Satisfied users UL TCH	Call block rate	Call drop rate	Handover Failure Rate	Handover rate vs. reference
0 dB / 0 dB	99.4 %	99.9 %	99.9 %	0.44 %	0 %	0 %	-
2 dB / 2 dB	100 %	99.7 %	99.8 %	0.31 %	0.1 %	0.09 %	+0.5 %
4 dB / 4 dB	100 %	100 %	100 %	0.11 %	0 %	0 %	-10.0 %
6 dB / 6 dB	100 %	100 %	100 %	0.12 %	0 %	0 %	-15.6 %

Power consumption metrics in terms of reduction in cumulative output power and reduction in overall TRX power consumption per cell are shown in table 8.3-10b for this scenario.

Table 8.3-10b: Power consumption metrics

Power reduction on idle TS / TS_{TCH}	Mean cumulated output power per cell [dBm]	Reduction of cumulated output power per cell [dB]	Reduction of TRX power consumption per cell
0 dB / 0 dB	43.1	-	-
2 dB / 2 dB	42.2	0.9	4.1 %
4 dB / 4 dB	41.7	1.4	6.9 %
6 dB / 6 dB	41.3	1.8	9.2 %

Observations:

- Satisfied user rates: the required level of 95 % is met in all cases, the actual levels being between 99 % and 100%.
- Call block rate: decreases along the level of power reduction. This is reasoned by the slightly increased good server cells, see Figures 8.3-2 and 8.3-3. In all cases it remains far below 2%. It includes blocking both due to capacity and due to insufficient radio quality.
- Handover failure rate: Handover failures are observed only for one power reduction setting (2 dB / 2 dB) in rare cases.
- Call drop rate: Handover failures impact the call drop rate which is below the required level of 0.2 %.
- Handover rate: is significantly reduced along the level of power reduction. A reduction of up to 15.6 % is achieved.
- Cumulated TRX power consumption: reduction is observed to go up to 9.2 %.

8.3.2.7 Impact on performance of neighbour cell identification in connected mode

The impact of power reduction on BCCH carrier on the performance of neighbour cell identification was investigated for MS's in connected mode for a medium traffic load scenario. The measurement of neighbour cells in connected mode follows the description in clauses 6.5.1.2 and 6.5.3 of the present document.

The modelling parameters for connected mode operation are summarized in table 8.3-11.

Table 8.3-11: Additional modelling parameters for connected mode operation

Parameter	Value	Unit	Comment
Scenario	S3		
Cell size	2000	m	Rural
Number of samples per neighbour cell per SACCH frame	8		
BSIC detection rate	9.6	sec	Per neighbour cell ([6], clause 7.2 requires at least every 10 sec)
CIR threshold for detection of BSIC failure	8 / 7	dB	for non-DARP MS / DARP MS
Simulated time	50 000 TDMA frames		Equals about 230 sec

Modelling of BSIC detection for neighbour cells is done with a periodicity of 20 SACCH multiframes, i.e. 9.6 sec , for each neighbour cell during the active connection. To identify the impact on handover measurements, the number of BSIC decodable neighbour cells from the BA list, which determines the number of cells included in the neighbour cell measurement report, has been logged during the simulation and the average was calculated over the simulated time and all MSs and was compared against the reference without power reduction. Figure 8.3-2 depicts for the investigated scenario the difference in mean number of BSIC decodable neighbour cells in connected mode.

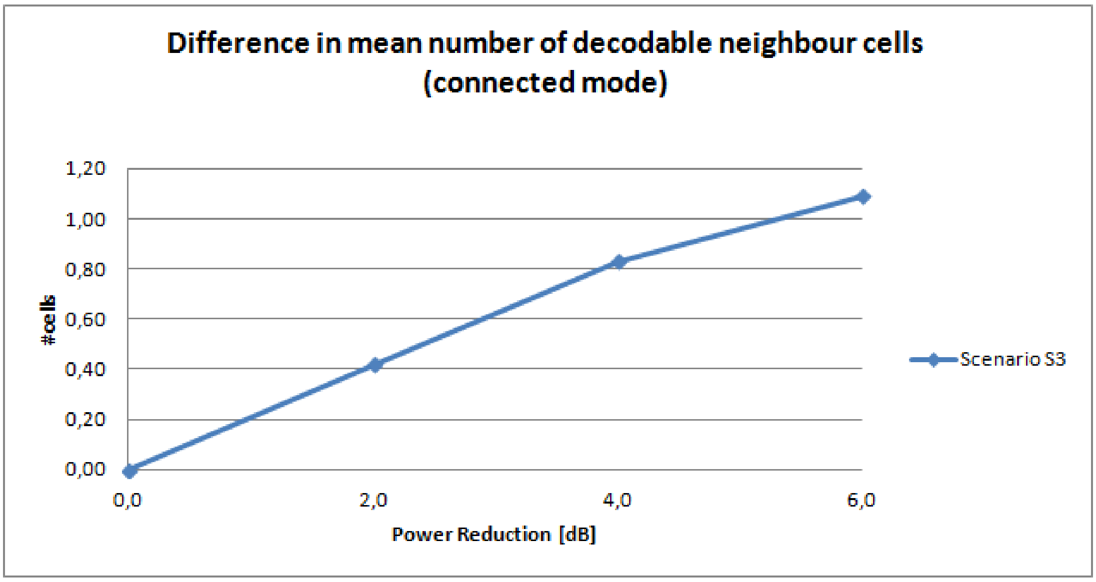

Figure 8.3-2: Difference in mean number of BSIC decodable neighbour cells as function of the power reduction on BCCH carrier for the investigated scenario S3

It is observed that the mean number of neighbour cells which can be decoded during the call (i.e. good neighbour cells) in order to perform an intercell handover steadily increases along the maximum power reduction in the considered APD range. The relative gain for the investigated scenario S3 versus the reference (no power reduction) is 0.42 cells (2 dB power reduction), 0.83 cells (4 dB power reduction) and 1.09 cells (6 dB power reduction) from the set of 12 neighbour cells the MS continuously measures. This investigation confirms the behaviour already observed in [5]. Thus BCCH power reduction overall has a positive impact on the number of BSIC decodable neighbour cells in connected mode.

8.3.2.8 Impact on performance of neighbour cell identification in idle mode

The impact of power reduction on BCCH carrier on the performance of neighbour cell identification was also investigated for MS's in idle mode for a medium traffic load scenario. The measurement of neighbour cells in idle mode follows the description in clause 6.5.1.1 of the present document.

The modelling parameters for idle mode operation are summarized in table 8.3-12.

Table 8.3-12: Additional modelling parameters for idle mode operation

Parameter	Value	Unit	Comment
Scenario	S3		
Cell size	2000	m	Rural
BS_PA_MFRMS	4		DRX period = 942 ms
Number of samples per serving cell for cell reselection	20		4 paging bursts per DRX period
Number of samples per neighbour cell for cell (re)selection	5		1 sample per DRX period
Cell (re)selection	based on C2 criterion		5 dB offset for cell reselection within 15 sec after last one, acc. to [6]
BSIC detection rate	4.7	sec	([6] requires to measure the six strongest carriers once per reselection period (=5 sec) and BSIC detection of each neighbour cell at least every 30 sec)
CIR threshold for detection of BSIC failure	8 / 7	dB	for non-DARP MS / DARP MS
Idle mode duration	28.2	sec	Allowing 6 subsequent cell reselections after initial cell selection, followed by call set up procedure
Simulated time	50 000 TDMA frames		Equals about 230 sec

Neighbour cell identification performance in idle mode was assessed by recording the number of BSIC decodable neighbour cells from the list of non-serving strongest 6 neighbour cells belonging to the BA list, after power ranking. This list was recorded at cell reselection instants for all MSs. A BSIC detection rate for reconfirmation of the 6 strongest neighbours of 4.7 sec was assumed for accurate modelling of the idle mode operation allowing for 6 cell reselections before call set-up is initiated. The average over the simulated time and all MSs was then calculated and was compared against the reference without power reduction. Figure 8.3-3 depicts for the investigated scenario the difference in mean number of BSIC decodable neighbour cells in idle mode.

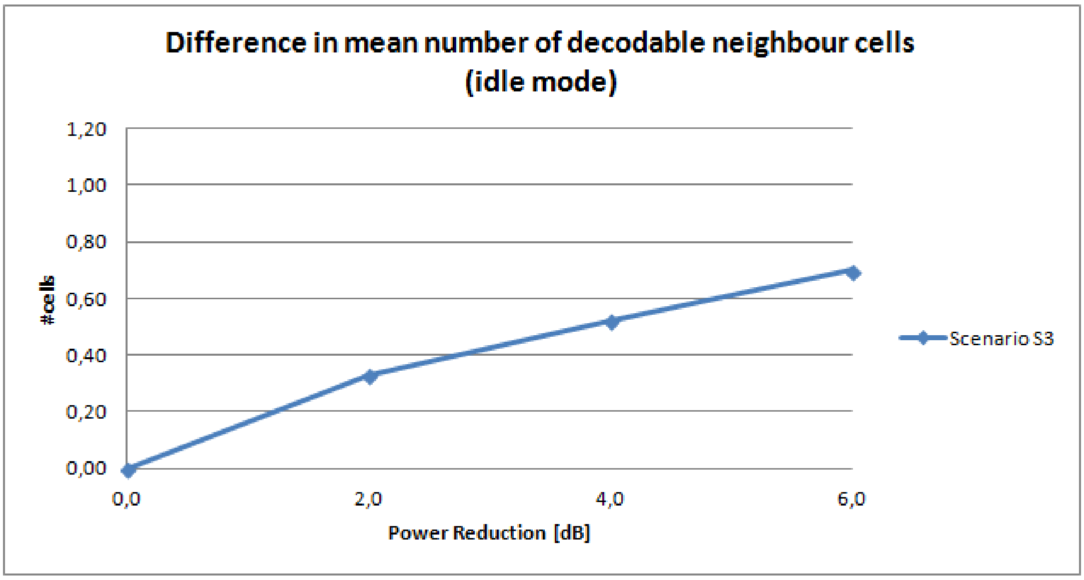

Figure 8.3-3: Difference in mean number of BSIC decodable neighbour cells in idle mode at cell reselection instants as function of the power reduction on BCCH carrier for the investigated scenario S3

It is observed that the mean number of cells which can be BSIC decoded at cell reselection instants steadily increases also here along the maximum power reduction in the considered APD range. The relative gain for the investigated scenario S3 versus the reference (no power reduction) is 0.33 cells (2 dB power reduction), 0.52 cells (4 dB power reduction) and 0.70 cells (6 dB power reduction) from the set of strongest 6 neighbour cells the MS continuously monitors. Thus BCCH power reduction overall has a positive impact on the number of BSIC decodable neighbour cells also in idle mode.

For the idle mode operation, the number of cell reselections was evaluated and the relative decrease compared against the reference case is reported in Table 8.3-13.

Table 8.3-13: Relative decrease in cell reselections in idle mode (Scenario S3)

Power reduction on idle TS / TS_{TCH}	Relative decrease in cell reselections [%]
0 dB / 0 dB	-
2 dB / 2 dB	13.3
4 dB / 4 dB	0
6 dB / 6 dB	36.7

Thus a significant reduction of the number of cell reselections in idle mode is observed. This is in line with the reduction of intercell handovers depicted for Scenario 3 in Table 8.3-7a.

8.3.2.9 Results for the alternative MS velocity

8.3.2.9.1 Scenario S5

Call quality metrics are shown in table 8.3-14a for DL and UL for the alternative MS velocity of 50 km/h, where separate statistics for DL are recorded for traffic channels on BCCH layer and TCH layer.

Table 8.3-14a: Call quality metrics

Power reduction on idle TS / TS_{TCH}	Satisfied users DL TCH	Satisfied users DL BCCH	Satisfied users UL TCH	Call block rate	Call drop rate	Handover Failure Rate	Handover rate vs. reference
0 dB / 0 dB	99.2 %	91.4 %	97.7 %	1.59 %	0.0 %	0.0 %	-
2 dB / 2 dB	98.8 %	93.6 %	98.8 %	2.10 %	0.36 %	0.35 %	-3.2 %
4 dB / 4 dB	97.1 %	90.3 %	99.1 %	0.64 %	0.63 %	0.53 %	+11.3 %
6 dB / 6 dB	95.4 %	91.7 %	98.2 %	0.36 %	0.54 %	0.62 %	-13.3 %

Power consumption metrics in terms of reduction in cumulative output power and reduction in overall TRX power consumption per cell are shown in table 8.3-14b for this scenario.

Table 8.3-14b: Power consumption metrics

Power reduction on idle TS / TS_{TCH}	Mean cumulated output power per cell [dBm]	Reduction of cumulated output power per cell [dB]	Reduction of TRX power consumption per cell
0 dB / 0 dB	43.2	-	-
2 dB / 2 dB	41.9	1.3	7.2 %
4 dB / 4 dB	41.1	2.1	11.6 %
6 dB / 6 dB	40.3	2.9	16.3 %

Observations:

- Satisfied user rates: the required level of 95 % is fulfilled for UL, but cannot be met for all DL channels, neither for the reference nor for the candidate configurations. In particular channels on the BCCH layer are impacted.

- Call block rate: remains below or close to 2%. It includes blocking both due to capacity and due to insufficient radio quality. It is observed to decrease along power reduction in this scenario as an increased number of cells can be BSIC decoded in idle mode (see clause 8.3.2.9.4).

- Handover failure rate: Handover failures are more often than for the reference velocity. They are observed for all three power reduction settings.

- Call drop rate: Handover failures impact the call drop rate being around 0.4-0.6% and hence above the required level of 0.2 % except for the reference setting (0 dB/0 dB).

- Handover rate: is significantly reduced along the level of power reduction with the exception of the 4 dB power reduction case. A reduction of up to about 13 % is achieved.

- Cumulated TRX power consumption: reduction is observed to go up to about 16.3 %.

8.3.2.9.2 Scenario S6

Call quality metrics are shown in table 8.3-15a for DL and UL for the alternative MS velocity of 50 km/h, where separate statistics for DL are recorded for traffic channels on BCCH layer and TCH layer.

Table 8.3-15a: Call quality metrics

Power reduction on idle TS / TS_{TCH}	Satisfied users DL TCH	Satisfied users DL BCCH	Satisfied users UL TCH	Call block rate	Call drop rate	Handover Failure Rate	Handover rate vs. reference
0 dB / 0 dB	95.2 %	91.4 %	96.8 %	2.23 %	0.54 %	0.34 %	-
2 dB / 2 dB	95.4 %	94.3 %	96.3 %	1.26 %	0.97 %	0.60 %	-11.4 %
4 dB / 4 dB	93.7 %	92.6 %	96.4 %	0.89 %	1.03 %	0.70 %	-2.8 %
6 dB / 6 dB	92.3 %	91.6 %	96.5 %	0.79 %	1.08 %	0.61 %	+3.1 %

Power consumption metrics in terms of reduction in cumulative output power and reduction in overall TRX power consumption per cell are shown in table 8.3-15b for this scenario.

Table 8.3-15b: Power consumption metrics

Power reduction on idle TS / TS_{TCH}	Mean cumulated output power per cell [dBm]	Reduction of cumulated output power per cell [dB]	Reduction of TRX power consumption per cell
0 dB / 0 dB	43.6	-	-
2 dB / 2 dB	42.5	1.1	5.9 %
4 dB / 4 dB	41.9	1.7	9.5 %
6 dB / 6 dB	41.4	2.2	12.1 %

Observations:

- Satisfied user rates: the required level of 95 % is fulfilled for UL, but cannot be met for all DL channels, neither for the reference nor for the candidate configurations. In particular channels both on the BCCH layer and in some cases on the TCH layer are impacted.

- Call block rate: remains below or close to 2%. It includes blocking both due to capacity and due to insufficient radio quality. It is observed to decrease along power reduction in this scenario as an increased number of cells can be BSIC decoded in idle mode (see clause 8.3.2.9.4).

- Handover failure rate: Handover failures are more often than for the reference velocity. They are observed for the reference and all three power reduction settings in this scenario.

- Call drop rate: Handover failures impact the call drop rate being around 0.55-1.1% and hence above the required level of 0.2 % for the reference and all three power reduction settings.

- Handover rate: is significantly reduced along the level of power reduction with the exception of the 4 dB power reduction case. A reduction of up to about 11.4 % is achieved.

- Cumulated TRX power consumption: reduction is observed to go up to about 12.1 %.

8.3.2.9.3 Impact on performance of neighbour cell identification in connected mode

The impact of power reduction on BCCH carrier on the performance of neighbour cell identification was also investigated for MS's in connected mode for medium and low traffic load scenarios for the alternative MS velocity. The modelling parameters are the same as described in clause 8.3.2.7. Figure 8.3-4 depicts for the investigated scenarios S5 and S6 the difference in mean number of BSIC decodable neighbour cells in connected mode.

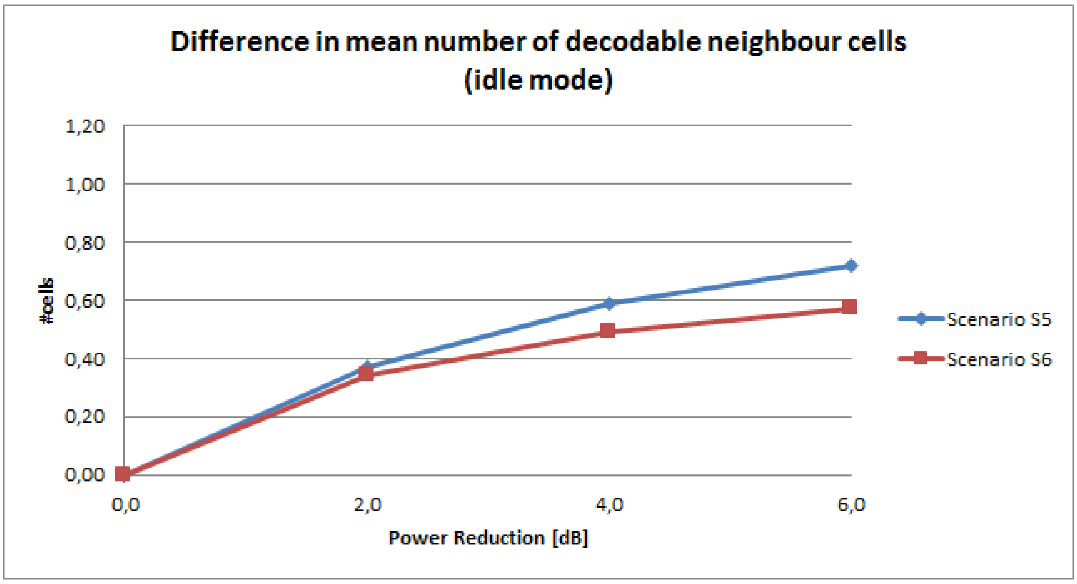

Figure 8.3-4: Difference in mean number of BSIC decodable neighbour cells as function of the power reduction on BCCH carrier for the investigated scenarios S5 and S6

It is observed that the mean number of neighbour cells which can be decoded during the call (i.e. good neighbour cells) in order to perform an intercell handover steadily increases along the maximum power reduction in the considered APD range. The relative gain for the investigated scenario S5 versus the reference (no power reduction) is 0.5 cells (2 dB power reduction), 0.84 cells (4 dB power reduction) and 1.22 cells (6 dB power reduction) from the set of 12 neighbour cells the MS continuously measures. For scenario S6 the corresponding figures are 0.44, 0.75 and 0.99 cells. Thus BCCH power reduction overall has a positive impact on the number of BSIC decodable neighbour cells in connected mode. It is in the same size as for the reference MS speed of 3 km/h.

8.3.2.9.4 Impact on performance of neighbour cell identification in idle mode

The impact of power reduction on BCCH carrier on the performance of neighbour cell identification was also investigated for MS's in idle mode for medium and low traffic load scenarios for the alternative MS velocity. The modelling parameters are the same as described in clause 8.3.2.8. Figure 8.3-5 depicts for the investigated scenarios S5 and S6 the difference in mean number of BSIC decodable neighbour cells in idle mode.

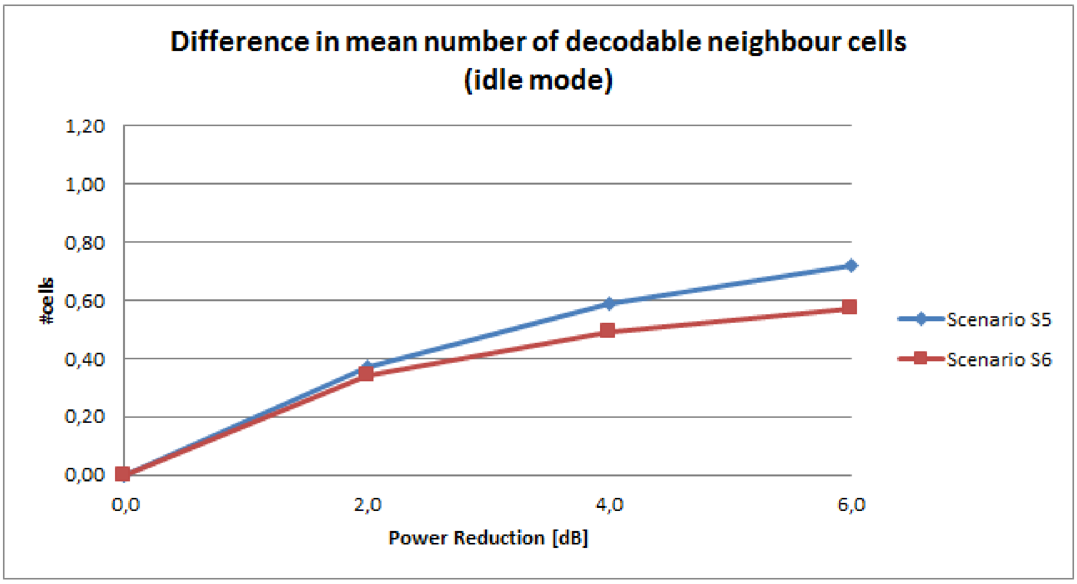

Figure 8.3-5: Difference in mean number of BSIC decodable neighbour cells in idle mode at cell reselection instants as function of the power reduction on BCCH carrier for the investigated scenarios S5 and S6

It is observed that the mean number of cells which can be BSIC decoded at cell reselection instants steadily increases also here along the maximum power reduction in the considered APD range, but lesser compared to the connected mode. The relative gain for the investigated scenario S5 versus the reference (no power reduction) is 0.37 cells (2 dB power reduction), 0.59 cells (4 dB power reduction) and 0.72 cells (6 dB power reduction) from the set of 12 neighbour cells the MS continuously measures. For scenario S6 the corresponding figures are 0.34, 0.49 and 0.57 cells. Thus BCCH power reduction overall has a positive impact on the number of BSIC decodable neighbour cells also in idle mode for the alternative MS velocity of 50 km/h.

For the idle mode operation and the alternative MS velocity of 50 km/h, the number of cell reselections was evaluated and the relative decrease compared against the reference case is reported in Table 8.3-16.

Table 8.3-16: Relative decrease in cell reselections in idle mode (Scenarios S5 and S6)

Power reduction on idle TS / TS_{TCH}	Relative decrease in cell reselections [%], S5	Relative decrease in cell reselections [%], S6
0 dB / 0 dB	-	-
2 dB / 2 dB	24.8	16.2
4 dB / 4 dB	15.5	10.1
6 dB / 6 dB	39.9	20.8

Also in this scenario a significant reduction of the number of cell reselections in idle mode is observed, the extent being dependent on the traffic load, i.e. for low traffic load the reduction in cell reselections is higher than for the medium traffic load for all power reduction configurations against the reference.

8.3.3 Impact to Specifications

This clause depicts the impact to GERAN specifications for the candidate solution investigated in clause 8.

In order to investigate the benefit of this candidate solution, the compatibility objective, i.e. the impact to legacy mobile stations has been studied in clause 8.3.2 with the result that no negative impact was identified in the considered APD range 2 dB…6 dB, instead a small positive impact on call quality and cell reselection performance was evaluated.

Thus for the specification work different options exist as listed below.

8.3.3.1 Option 1: no provision of signalling support

In this option no signalling support is defined for the power reduction on BCCH carrier.

Legacy mobiles and new mobiles are not aware of its usage by the network. This option has the property that a supporting MS needs to spend effort to detect the activation of this setting in the cell to improve the accuracy of power measurements for candidate cells. On the other side, moving from the legacy mode (hereafter called "normal operation") into the mode applying power reduction on the BCCH carrier (hereafter called "BCCH carrier power save mode operation") and vice versa can be done by the network without the need for broadcasting or signalling any change in the setting. For instance the network may decide to move from BCCH carrier power save mode operation into normal mode to serve higher traffic loads and may reduce the APD per each modulation stepwise along the traffic increase to reach the APD foreseen for normal operation. In return when the traffic load decreases the network can choose to apply higher APD values per each modulation to move to the BCCH carrier power save mode operation.

For realizing this option in the specifications, modification of TS 45.008, clause 7.1 is required, see the section below. This introduces the BCCH carrier power save mode. Corresponding changes to TS 45.008 v12.4.0 are shown using revision marks.

8.3.3.1.1 Example implementation of option 1 in the specifications

The following is a modified extract of TS 45.008 related to clause 7.1.

=========== Begin of modified extract of TS 45.008 ==============

7 Network pre-requisites

7.1 BCCH carriers

The BCCH carrier shall be continuously transmitted on all timeslots.

In normal operation, it shall be transmitted without variation of RF level in case all timeslots on BCCH carrier are GMSK modulated and else in case of different modulated timeslots with minimum variation of RF level as specified below. An exception applies in case the BTS enters the BCCH carrier power save mode, for the purpose of energy saving, where the variation of RF level for all timeslots on BCCH carrier, except timeslots carrying BCCH/CCCH, is relaxed as specified below.

The RF power level may be ramped down between timeslots for instance to facilitate switching between RF transmitters.

A BTS that is switching transmission between two or more antennas, shall use the same antenna for transmission on a CCCH slot and the slot immediately preceding the CCCH slot (i.e. antenna switching shall be avoided immediately before a CCCH slot in order to avoid unpredictable path loss changes at this point).

In normal operation, for timeslots on the BCCH carrier which are transmitted with modulations other than GMSK, the output power (as defined in 3GPP TS 45.005) may be lower than the output power used for GMSK modulated timeslots. In this case, the maximum allowed difference in output power actually transmitted by the BTS is listed for each respective modulation of EGPRS, EGPRS2 and VAMOS in the table below.

In BCCH carrier power save mode operation, for timeslots on the BCCH carrier which are transmitted with GMSK or modulations other than GMSK, except timeslots carrying BCCH/CCCH, the output power (as defined in 3GPP TS 45.005) may be lower than the output power used for timeslots carrying BCCH/CCCH. In this case the maximum allowed difference in output power actually transmitted by the BTS for each respective modulation of GSM, GPRS, EGPRS, EGPRS2 and VAMOS is 6 dB.

Furthermore, in normal operation and in BCCH carrier power save mode operation, between a timeslot used for BCCH/CCCH and the timeslot preceding it, the difference in output power actually transmitted by the BTS shall not exceed 3 dB.

NOTE: The allowed output power decrease does not refer to a difference between nominal power levels, but to the difference in output power actually transmitted.

Maximum output power decrease on BCCH carrier in normal operation.

	Modulation	Output Power Decrease
EGPRS	8PSK	4 dB
EGPRS2-A	16QAM	6 dB
EGPRS2-A	32QAM	6 dB
EGPRS2-B	QPSK	4 dB
EGPRS2-B	16QAM	6 dB
EGPRS2-B	32QAM	6 dB
VAMOS	AQPSK	4 dB

The MS requirements on signal strength measurements are defined for normal operation of the BTS for the case when only GMSK modulation is used on the BCCH carrier. There are no defined signal strength measurement requirements for the MS in BCCH carrier power save mode or if other modulations are used on the BCCH carrier.

On the PCH the network shall send valid layer 3 messages according to 3GPP TS 44.018. Unused signalling blocks on the CCCH/BCCH shall contain L2 fill frames. Other unused timeslots shall transmit dummy bursts.

The number of neighbour cell BCCH carriers in the BCCH allocation shall not exceed 32.

NOTE 1: This BCCH organization enables MS to measure the received signal level from surrounding cells by tuning and listening to their BCCH carriers. Providing that an MS tunes to the list of BCCH carriers indicated by the network it will, providing the list is sufficiently complete, have listened to all possible surrounding cells, i.e. the surrounding cell list for handover purposes is effectively defined by the MS. Refer to 3GPP TS 43.022 for definitions of the BCCH carrier lists. This can be achieved without inter-base station synchronization.

NOTE 2: If the operator decides to allow for the usage of modulation types other than GMSK on the BCCH carrier in certain cells, the cell selection, cell reselection and handover procedures involving these cells will be somewhat sub-optimal. This is due to the fact that the signal level measured by the MS at some instances in time will be affected by the possibly lower output power level of the 8-PSK modulation type used in EGPRS, and by the output power level of QPSK, 8-PSK, 16-QAM and 32-QAM modulation types used in EGPRS2, and by the AQPSK modulation used in VAMOS respectively, and by the power fluctuation resulting from these modulation types other than GMSK. The extent of the performance degradation is dependent upon the measurement schedule in each particular MS as well as upon the used output power decrease and the current load of the modulation types other than GMSK on the BCCH carrier. By limiting the maximum number of time slots, carrying modulation types other than GMSK, being simultaneously allowed on the BCCH carrier, and/or carefully selecting the values of involved network parameters, the impact on the above mentioned procedures may be minimised. Additionally, in areas with very low cell overlap, some coverage loss effects may have to be taken into account by the operator when selecting network parameters.

NOTE 3: In the case that QPSK, AQPSK, 8-PSK, 16-QAM or 32-QAM modulation s (see Note 2) are allowed on the BCCH carrier and frequency hopping including the BCCH carrier is used, the reception quality in connected mode for some fast moving MS (meaning MS experiencing Doppler frequencies of 100 Hz or more) may be degraded. This may be seen as a backwards compatibility problem for some existing MS, most likely occurring if the used APD is larger than 2 dB.

NOTE 4: In case the BTS supports operation in BCCH carrier power save mode, in order to yield network energy savings, the usage of this mode by the operator needs some consideration. For instance in areas with very low cell overlap, some coverage loss effects may have to be taken into account. Additionally the operated reduction of output power on timeslots of the BCCH carrier should be similar in neighbouring cells, i.e. the usage of this mode should not be applied cell specific, but applied to as many cells as possible in a certain geographic area. The benefit of this mode in busy hour times was investigated to be rather limited [TR 45.926]. Thus the actual level of operated power reduction on timeslots using GMSK modulation should generally be reduced along the increase of traffic load in cells and may be selected to be higher for idle timeslots than for occupied timeslots. Usage of power reduction on timeslots carrying SDCCH in BCCH carrier power save mode is not recommended.

===========   End of modified extract of TS 45.008 =============

8.3.3.2 Option 2: provision of mobile station signalling support

To enable the network to decide on application of the BCCH carrier power save mode and the level of power reduction based on the penetration of new mobile stations supporting the BCCH carrier power save mode operation, the network is made aware of the MS capability signalled at network attach indicating the support of this feature. The capability is signalled as part of the Rel-13 features in TS 24.008 in MS CM3 and MS RAC. A single bit is required for the support of this feature. In addition for verifying the improved neighbour cell detection performance of the MS a test needs to be specified (e.g. in TS 45.008) such that the MS identifies the strongest candidate cell for a set of candidate cells with active BCCH carrier power save mode in a predefined time interval (neighbour cell identification test in BCCH carrier power save mode).

It is noted that option 2 includes the modification to TS 45.008 as depicted for option 1. In addition clause 7.1 of TS 45.008 needs to include MS requirements applicable in BCCH carrier power save mode by referring to the new neighbour cell identification test.

This option can be specified independently from option 3, i.e. in combination or in standalone manner.

8.3.3.2.1 Example implementation of option 2 in the specifications

The following is an extract of clause 10.5.1.7 (Mobile Station Classmark 3) of TS 24.008. For MS RAC (clause 10.5.5.12a MS Radio Access capability) the corresponding changes apply.

=========== Begin of modified extract of TS 24.008 ==============

```
<Classmark 3 Value part> ::=

…
     < ER Band Support : bit >    -- Release 12 starts here
     < UTRA Multiple Frequency Band Indicators support : bit >
     < E-UTRA Multiple Frequency Band Indicators support: bit >
     < Extended TSC Set Capability support: bit >
     < Extended EARFCN value range : bit >    -- Late addition of a release 11 feature
     < spare bits > ;

     < BCCH carrier power save mode Support : bit >  -- Release 13 starts here

< A5 bits > ::=
     < A5/7 : bit > < A5/6 : bit > < A5/5 : bit > < A5/4 : bit >  ;

<R Support>::=
     < R-GSM band Associated Radio Capability : bit(3) > ;

< HSCSD Multi Slot Capability > ::=
     < HSCSD Multi Slot Class : bit(5) >  ;

< MS Measurement capability > ::=
     < SMS_VALUE : bit (4) >
     < SM_VALUE : bit (4) > ;

< MS Positioning Method Capability > ::=
     < MS Positioning Method : bit(5) > ;

< ECSD Multi Slot Capability > ::=
     < ECSD Multi Slot Class : bit(5) > ;

 < 8-PSK Struct> : :=
     < Modulation Capability : bit >
     { 0 | 1 < 8-PSK RF Power Capability 1: bit(2) > }
     { 0 | 1 < 8-PSK RF Power Capability 2: bit(2) > }

< Single Band Support > ::=
     < GSM Band : bit (4) > ;
```

Figure 10.5.1.7/3GPP TS 24.008 *Mobile Station Classmark 3* information element

Table 10.5.1.7/3GPP TS 24.008 (continued): *Mobile Station Classmark 3* information element

…

ER Band Support (1 bit field)
This field indicates whether the mobile station supports ER-GSM band (see 3GPP TS 45.005 [33]). It is coded as follows:

Bit
0 ER-GSM not supported
1 ER-GSM supported

NOTE: When ER-GSM is supported, the associated RF power capability is found in Mobile Station Classmark 1, Mobile Station Classmark 2 and/or Mobile Station Classmark 3. The ER-GSM band associated radio capability is the same as for the R-GSM band (see R-GSM band Associated Radio Capability).

UTRA Multiple Frequency Band Indicators support (1 bit field)
This field indicates whether the mobile station supports multiple radio frequency bands in UTRAN (see 3GPP TS 25.331 [23c]) and whether it understands signalling of overlapping UTRA frequency bands (see 3GPP TS 44.018 [84]). It is coded as follows:

Bit
0 Multiple Frequency Band Indicators in UTRAN not supported
1 Multiple Frequency Band Indicators in UTRAN supported

E-UTRA Multiple Frequency Band Indicators support (1 bit field)
This field indicates whether the mobile station supports multiple radio frequency bands in E-UTRAN (see 3GPP TS 36.331 [129]) and whether it understands signalling of overlapping E-UTRA frequency bands (see 3GPP TS 44.018 [84]). It is coded as follows:

Bit
0 Multiple Frequency Band Indicators in E-UTRAN not supported
1 Multiple Frequency Band Indicators in E-UTRAN supported

Extended TSC Set Capability support (1 bit field)
This field indicates whether the mobile station supports the extended TSC sets when operating in the PS or CS domain (see 3GPP TS 45.002 [32]). It is coded as follows:

Bit
0 Extended TSC sets not supported
1 Extended TSC sets supported

Extended EARFCN value range (1 bit field)
This field indicates whether the mobile station supports the extended EARFCN value range in GERAN (see 3GPP TS 44.018 [84]). It is coded as follows:

Bit
0 Extended EARFCN value range not supported
1 Extended EARFCN value range supported

BCCH carrier power save mode Support (1 bit field)
This field indicates whether the mobile station supports the BCCH carrier power save mode (see 3GPP TS 44.018 [84] and 3GPP TS 45.008 [34]). It is coded as follows:

Bit
0 BCCH carrier power save mode not supported
1 BCCH carrier power save mode supported

=========== End of modified extract of TS 24.008 =============

8.3.3.3 Option 3: provision of network signalling support

In this option signalling support is defined for the power reduction on BCCH carrier being initiated by the network.

Thus new mobiles supporting the BCCH carrier power save mode operation can be made aware of the non-constant output power on BCCH carrier due to this mode if indicated by the base station in order to improve accuracy of received power measurements in regard to the cell's carrier output power for candidate cell measurements.

To this purpose for idle and connected mode operation the network broadcasts on the BCCH of each cell, if power reduction is enabled on BCCH carrier of this cell for all timeslots except those used for BCCH/CCCH, i.e. if it operates the BCCH carrier power save mode. This indication may be sent as part of System information, e.g. as part of the Control Channel Description included in System Information Type 3, as depicted in the subsection below. Changes to TS 44.018 v12.6.0 are shown using revision marks. Since SI 3 is sent when TC=2 and TC=6 (acc. to TS 45.002), acquisition time is about 1 sec to read this information. It is assumed that for a suitable candidate cell after BSIC detection this time is acceptable to be taken into account in possible subsequent cell reselections.

It is noted that option 3 includes the modification to TS 45.008 as depicted for option 1. It can be specified independently from option 2, i.e. in combination or in standalone manner.

8.3.3.3.1 Example implementation of option 3 in the specifications

The following is an extract of clause 10.5.2.11 of TS 44.018.

=========== Begin of modified extract of TS 44.018 ==============

10.5.2.11 Control Channel Description

The purpose of the *Control Channel Description* information element is to provide a variety of information about a cell.

The *Control Channel Description* information element is coded as shown in figure 10.5.2.11.1 and table 10.5.2.11.1.

The *Control Channel Description* is a type 3 information element with 4 octets length.

<table>
<tr><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td></td></tr>
<tr><td></td><td colspan="7">Control Channel Description IEI</td><td>octet 1</td></tr>
<tr><td>MSCR</td><td>ATT</td><td colspan="3">BS-AG-BLKS-RES</td><td colspan="3">CCCH-CONF</td><td>octet 2</td></tr>
<tr><td>SI22IND</td><td colspan="2">CBQ3</td><td>BCCH-PWR-SAVE</td><td>0
spare</td><td colspan="3">BS-PA-MFRMS</td><td>octet 3</td></tr>
<tr><td colspan="8">T 3212
time-out value</td><td>octet 4</td></tr>
</table>

Figure 10.5.2.11.1: *Control Channel Description* information element

Table 10.5.2.11.1: *Control Channel Description* information element

MSCR, MSC Release (octet 2)
Bit
8
0 MSC is Release '98 or older
1 MSC is Release '99 onwards
ATT, Attach-detach allowed (octet 2)
Bit
7
0 MSs in the cell are not allowed to apply IMSI attach and detach procedure.
1 MSs in the cell shall apply IMSI attach and detach procedure.

BS-AG-BLKS-RES (octet 2)
The BS-AG-BLKS-RES field is coded as the binary representation of the number of blocks reserved for access grant.

Range
0 to 2 if CCCH-CONF = "001"
0 to 7 for other values of CCCH-CONF
All other values are reserved in the first case

CCCH-CONF (octet 2)
bits
3 2 1
0 0 0 1 basic physical channel used for CCCH, not combined with SDCCHs
0 0 1 1 basic physical channel used for CCCH, combined with SDCCHs
0 1 0 2 basic physical channel used for CCCH, not combined with SDCCHs
1 0 0 3 basic physical channel used for CCCH, not combined with SDCCHs
1 1 0 4 basic physical channels used for CCCH, not combined with SDCCHs
all other values are reserved

SI22IND, SYSTEM INFORMATION TYPE 22 indicator (octet 3)
Bit
8
0 SI22 is not broadcast.
1 SI22 is broadcast.

CBQ3, Cell Bar Qualify 3 (octet 3)
Bits
7 6
0 0 *Iu mode* not supported
0 1 *Iu mode* capable MSs barred
1 0 *Iu mode* supported, cell not barred
1 1 *Iu mode* supported, cell not barred. The network shall not use this value.

BCCH-PWR-SAVE, BCCH carrier power save mode (octet 3)
Bit
5
0 BCCH carrier power save mode is not used
1 BCCH carrier power save mode is used

NOTE: See 3GPP TS 45.008 for information on Cell Bar Qualify 3 and BCCH carrier power save mode.

BS-PA-MFRMS (octet 3) Bits 3 2 1 0 0 0 2 multiframes period for transmission of PAGING REQUEST messages to the same paging subgroup 0 0 1 3 multiframes period for transmission of PAGING REQUEST messages to the same paging subgroup 0 1 0 4 multiframes period for transmission of PAGING REQUEST messages to the same paging subgroup. . . 1 1 1 9 multiframes period for transmission of PAGING REQUEST messages to the same paging subgroup NOTE: The number of different paging subchannels on the CCCH is: MAX(1,(3 - BS-AG-BLKS-RES)) * BS-PA-MFRMS if CCCH-CONF = "001" (9 - BS-AG-BLKS-RES) * BS-PA-MFRMS for other values of CCCH-CONF **T3212** timeout value (octet 4) The T3212 timeout value field is coded as the binary representation of the timeout value for periodic updating in decihours. Range: 1 to 255 The value 0 is used for infinite timeout value i.e. periodic updating shall not be used within the cell.

NOTE: The MSC Release bit indicates the version of the MSC specific protocols and is not applicable to access stratum protocols.

=========== End of modified extract of TS 44.018 ==============

8.4 Conclusion

The candidate technique 'output power reduction on BCCH carrier for GMSK' described in this clause has been evaluated for a series of scenarios, both for the coverage layer and the capacity layer for the small site configuration S(2/2/2) and the medium site configuration S(4/4/4) for low mobility users and for the voice-only traffic scenario. From the results for the reference MS velocity of 3 km/h it can be seen that in the investigated power reduction range (APD range) up to 6 dB, savings in cumulated TRX power consumption up to 16 % are achieved for the small site configuration S(2/2/2) and up to 9 % for the medium site configuration S(4/4/4), respectively, which is considered to be substantial.

With regard to call quality, the level of satisfied users of 95 % is met in all scenarios, the actual levels being all above 98.5 % except for the busy hour scenario (Scenario S4), where the levels decrease to 95.5 % at most.

With regard to reliability of the evaluation results, satisfied user rates on the BCCH carrier for the reference case in all investigated scenarios are close to each other (i.e. between 98.5 % and 100%) and are impacted by the handover penalty and handover rate in the different scenarios.

On the other side the handover rate is significantly reduced along the power reduction, the reduction being in the order of 15…27 % against the reference case depending on the scenario.

It is also observed that call blocking remains below 2% and call dropping rates are generally not degraded against the reference case (except in one scenario S1).

Impacts to neighbour cell identification performance in connected mode for intercell handover and in idle mode for cell reselection were also studied by evaluating the mean number of suitable candidate cells in idle and in connected mode. It was observed that for the medium traffic load scenario S3 the average number of suitable candidate cells is increased up to 0.70 cells in idle mode, and up to 1.09 cells in connected mode, respectively, for the configured set of 12 neighbour cells. In both cases the number of good neighbour cells is observed to steadily increase along the maximum power reduction in the considered APD range. Furthermore the number of cell reselections in idle mode is observed not to be increased compared to the reference case.

Power reduction on BCCH layer for the APD range 2 dB to 6 dB is supposed to improve system performance in interference limited scenarios yielding higher spectral efficiency. It is noted that this APD range corresponds to the allowed reduction of output power on the BCCH carrier up to 4 dB for 8PSK and up to 6 dB for 16QAM and 32QAM ([6], clause 7.1).

Simulations have been also run for the capacity layer indicating the same level of power saving as described for the coverage layer.

Simulations have been also run for the alternative MS velocity of 50 km/h for the coverage layer and the small site configuration S(2/2/2). Also here BTS energy savings in cumulated TRX power consumption up to around 16 % are achieved for the low traffic load scenario and up to around 12 % for the medium traffic load scenario, respectively. In these scenarios due to the higher handover rate a negative impact to satisfied user rates in terms of higher speech frame loss due to handover penalty and a negative impact to handover failure rate are observed. Thus call drop rate increases along the power reduction from about 0.55 % (reference) to around 1.1% (6 dB power reduction). Neighbour cell identification performance is improved for power reduction configurations similar as for the reference MS velocity and cell reselections in idle mode are reduced in the range 10% to 40%. Thus power reduction on BCCH carrier for the investigated APD range and for the alternative MS velocity scenario is expected to yield sufficient system performance, provided there is sufficient cell overlap.

From the obtained results, it is observed that the BCCH power saving candidate technique employing an APD range of 2 dB… 6 dB depicts an attractive feature for operators in saving OPEX, in particular in low and medium traffic load scenarios where energy savings are larger than in the busy hour.

The impact on the specifications from introducing this candidate technique has also been analysed. Solutions both without signalling support (option 1) and with signalling support from the mobile station (option 2) and from the network (option 3), respectively, have been studied. Impacts to TS 45.008 specifying the maximum allowed output power decrease, to TS 44.018 to support the feature via broadcast signalling and to TS 24.008 to enable the mobile station to inform the network about its capability to support this feature have been described. The introduction of signalling support allows supporting new mobile stations to improve accuracy and faster acquisition of candidate cell measurements both in idle and connected mode. In order to allow for timely introduction of this feature, nevertheless option 1 is proposed to be specified in Rel-13, whilst option 2 and option 3 may serve as future enhancements for new mobile stations combined with the support of other features.

9 Summary and Conclusions

The BTSEnergy study has investigated candidate techniques for BTS energy saving solutions. The major focus in the study was on energy saving in regard to RF output power reduction. In particular RF output power reduction for the BCCH carrier was investigated for different scenarios in regard to traffic load profiles (low load, medium term load and busy hour load) and site configurations (three sectorized sites with 2 TRX, 4TRX and 8 TRX per cells). The study has defined performance objectives and compatibility objectives as depicted in clause 5.

In regard to the evaluation of candidate solutions, two performance metrics have been defined, one assessing the savings in cumulated RF output power over all carriers of the cell and one assessing the savings in cumulated TRX power consumption over all TRXs of the cell.

The candidate solution "BCCH Carrier Power Reduction Methodology", depicted in clause 7.1, foresees to reduce the transmit power on the BCCH carrier for idle timeslots and for timeslots used for traffic channels. Two variants have been investigated, one applying power reduction for traffic channels only for DTX silence periods (variant 1) and one applying power reduction for traffic channels both for DTX silence and active periods (variant 2). The level of power reduction of 2 dB against the reference case, not applying any power reduction, was evaluated for both variants for different load profiles and different site configurations defined as part of the common assumptions in clause 6. The candidate has impacts to network KPI. The total handover number slightly decreases when it is applied. The percentage of satisfied users may decrease but be within a 95% target in most cases, especially when the reference case meets the target. It also has limited impacts to the call drop rate. It was observed that the investigated power reduction for the BCCH carrier is up to 12.5 % for the small site configuration S(2/2/2) and up to 10 % for the medium site configuration S(4/4/4), respectively. It is noted that the evaluation was not in alignment with the common assumptions in clause 6.2 requiring the evaluation of the cumulated TRX power consumption over all carriers of the base station. Thus the observed gains can be seen rather as indicative for a possible significant power saving.

The candidate solution "Output Power Reduction on BCCH Carrier for GMSK", depicted in clauses 8.1 and 8.2 (concept description), foresees to apply a reduced output power on the BCCH carrier for all time slots carrying GMSK modulation except time slots carrying BCCH and CCCH channels as well as timeslots preceding them. For the latter a limited power reduction of up to 2 dB is proposed, whilst for the other time slots a reduction in the range 2 dB to 6 dB is proposed. The concept is evaluated in clause 8.3 investigating both call quality metrics and power consumption metrics. According to the candidate's conclusion in clause 8.4 the considered APD range 2dB…6 dB, which is identical to that one allowed for higher order modulations on BCCH carrier in [6], will generally have a positive impact on call quality metrics – such as satisfied user rates, handover failures and call drops – when compared against the reference case not applying any power reduction on BCCH carrier. In addition a small positive impact on cell reselection performance in idle mode is observed. In regard to power consumption metrics, the candidate solution for small and medium size configurations at different traffic loads and for MS velocities of 3 km/h and 50 km/h has shown to yield improvements in output power reduction up to 2.8 dB and savings in cumulated TRX power consumption up to 16 % for the small site configuration S(2/2/2) and up to 9 % for the medium site configuration S(4/4/4), respectively, which is considered to be substantial.

Thus it is proposed to proceed along the depicted approach in clause 8.4 in the normative work in order to allow the network to configure the BCCH carrier power save mode for the purpose of network energy savings.

Annex A: Bibliography

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Annex B: Change history

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**
11-2015	68	GP-151223			Approved at GP#68		13.0.0

Change history							
Date	**Meeting**	**TDoc**	**CR**	**Rev**	**Cat**	**Subject/Comment**	**New version**
2017-03	RP-75	-	-	-	-	Version for Release 14 (frozen at TSG-75)	14.0.0
2018-06	RP-80	-	-	-	-	Version for Release 15 (frozen at TSG-80)	15.0.0
2020-07	RP-88e	-	-	-	-	Upgrade to Rel-16 version without technical change	16.0.0

History

Document history		
V16.0.0	September 2020	Publication