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Technical Report

Satellite Earth Stations and Systems (SES); Satellite Component of UMTS/IMT-2000; W-CDMA Radio Interface for Multimedia Broadcast/Multicast Service (MBMS)

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Contents

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Foreword

The present Technical Report (TR) has been produced by ETSI Technical Committee Satellite Earth Stations and Systems (SES).

Introduction

The objective of W-CDMA Satellite Radio Interface is to ease integration of satellite and terrestrial UMTS. One promising application is provision of Multimedia Broadcast/Multicast Service (MBMS). Some of the benefits to be gained from a fully integrated S-UMTS/T-UMTS system are:

- seamless service provision;
- highly integrated multi-mode terrestrial/satellite User Equipment (UE);
- reuse of terrestrial equipment: radio access infrastructure equipment (RNC, Node B, etc.).

The satellite component of MBMS may provide services:

- in areas covered by cellular terrestrial systems, for complementary services such as broadcast/multicast;
- in areas where terrestrial coverage is not available:
    - because terrestrial network have not been deployed for business attractiveness reasons; or
    - because terrestrial infrastructure has suffered environmental damages (crisis conditions).

The present document is applicable to several satellite constellation types (for LEO and MEO constellations, addition of Doppler and synchronization adaptation module).

The outline of the present document is the following:

- Clause 4: "Satellite Multimedia Broadcast/Multicast Service", the system architecture and candidate satellite constellations are presented.
- Clause 5: "W-CDMA Satellite Radio Interface" summarizes key characteristics based on the Technical Specifications defined by 3GPP.
- Clause 6 specifies test environment and equipment performance requirements.
- Clause 7: "System performances" presents link budgets and system capacity.

- Clause 8: "Technology design constraints" summarizes constraints due to satellite environment.
- The concluding clause 9 "Conclusion" is a brief summary of the results established so far.

The present document is completed with four annexes. Annex A specifies reference measurement channels. Annexes B, C and D present Comparison of S-MBMS performance and system radio capacity with and without soft combining in IMR environment.

1 Scope

The feasibility of using W-CDMA UTRA FDD as a satellite radio interface has been shown in ETSI TR 102 058 [6]. Based on this, ITU has adopted this radio interface as G family in ITU-Rec M 1455 [3] and ITU-Rec M 1457 [4]. This radio interface has been standardized within the TC SES S-UMTS working group as family G in TS 101 851-1 to 4 [7] to [10].

The present document evaluates the feasibility to use S-UMTS interface G (W-CDMA UTRA FDD) for provision of Satellite Multimedia Broadcast/Multicast Service (S-MBMS).

The Technical Specifications for the W-CDMA UTRA FDD has been developed in the framework of the third Generation Partnership project (3GPP). The analysis for applicability to satellite is based on 3GPP standards as defined from [11] to [29].

2 References

For the purposes of this Technical Report (TR), the following references apply:

[1] ETSI TR 101 865: "Satellite Earth Stations and Systems (SES); Satellite component of UMTS/IMT-2000; General aspects and principles".

[2] ITU-R Recommendation M.1225: "Guidelines for evaluation of Radio Transmission technology for IMT-2000".

[3] ITU-R Recommendation M.1455: "Key characteristics for the International Mobile Telecommunications-2000 (IMT-2000) radio interfaces".

[4] ITU-R Recommendation M.1457: "Detailed specifications of the radio interfaces of the International Mobile Telecommunications-2000 (IMT-2000)".

[5] ITU-R Recommendation M.1034-1: "Requirements for the radio interface(s) for International Mobile Telecommunications-2000 (IMT-2000)".

[6] ETSI TR 102 058: "Satellite Earth Stations and Systems (SES); Satellite Component of UMTS/IMT-2000; Evaluation of the W-CDMA UTRA FDD as a Satellite Radio Interface".

[7] ETSI TS 101 851-1: "Satellite Earth Stations and Systems (SES); Satellite Component of UMTS/IMT2000; G-family; Part 1: Physical channels and mapping of transport channels into physical channels (S-UMTS-A 25.211)".

[8] ETSI TS 101 851-2: "Satellite Earth Stations and Systems (SES); Satellite Component of UMTS/IMT2000; G-family; Part 2: Multiplexing and channel coding (S-UMTS-A 25.212)".

[9] ETSI TS 101 851-3: "Satellite Earth Stations and Systems (SES); Satellite Component of UMTS/IMT2000; G-family; Part 3: Spreading and modulation (S-UMTS-A 25.213)".

[10] ETSI TS 101 851-4: "Satellite Earth Stations and Systems (SES); Satellite Component of UMTS/IMT2000; G-family; Part 4: Physical layer procedures (S-UMTS-A 25.214)".

[11] ETSI TS 125 101: "Universal Mobile Telecommunications System (UMTS); User Equipment (UE) radio transmission and reception (FDD) (3GPP TS 25.101)".

[12] ETSI TS 125 104: "Universal Mobile Telecommunications System (UMTS); Base Station (BS) radio transmission and reception (FDD) (3GPP TS 25.104)".

[13] ETSI TS 125 201: "Universal Mobile Telecommunications System (UMTS); Physical layer - general description (3GPP TS 25.201)".

[14] ETSI TS 125 301: "Universal Mobile Telecommunications System (UMTS); Radio interface protocol architecture (3GPP TS 25.301)".

[15] ETSI TS 125 302: "Universal Mobile Telecommunications System (UMTS); Services provided by the physical layer (3GPP TS 25.302)".

[16] ETSI TS 125 321: "Universal Mobile Telecommunications System (UMTS); Medium Access Control (MAC) protocol specification (3GPP TS 25.321)".

[17] ETSI TS 125 322: "Universal Mobile Telecommunications System (UMTS); Radio Link Control (RLC) protocol specification (3GPP TS 25.322)".

[18] ETSI TS 125 323: "Universal Mobile Telecommunications System (UMTS); Packet Data Convergence Protocol (PDCP) specification (3GPP TS 25.323)".

[19] ETSI TS 125 324: "Universal Mobile Telecommunications System (UMTS); Broadcast/Multicast Control (BMC) (3GPP TS 25.324)".

[20] ETSI TS 125 331: "Universal Mobile Telecommunications System (UMTS); Radio Resource Control (RRC); Protocol specification (3GPP TS 25.331)".

[21] ETSI TS 125 401: "13 UTRAN overall description (3GPP TS 25.401)".

[22] ETSI TS 125 402: "Universal Mobile Telecommunications System (UMTS); Synchronization in UTRAN Stage 2 (3GPP TS 25.402)".

[23] ETSI TS 125 141: "Universal Mobile Telecommunications System (UMTS); Base Station (BS) conformance testing (FDD) (3GPP TS 25.141)".

[24] ETSI TS 134 121: "Universal Mobile Telecommunications System (UMTS); User Equipment (UE) conformance specification; Radio transmission and reception (FDD); Part 1: Conformance specification (3GPP TS 34.121-1)".

[25] ETSI TR 125 942: "Universal Mobile Telecommunications System (UMTS); Radio Frequency (RF) system scenarios (3GPP TR 25.942)".

[26] ETSI TS 125 146: "Universal Mobile Telecommunications System (UMTS); Multimedia Broadcast/Multicast Service (MBMS); Stage 1 (3GPP TS 22.146)".

[27] ETSI TS 125.346: "Universal Mobile Telecommunications System (UMTS); Introduction of the Multimedia Broadcast/Multicast Service (MBMS) in the Radio Access Network (RAN); Stage 2 (3GPP TS 25.346)".

[28] ETSI TR 125 992: "Digital cellular telecommunications system (Phase 2+); Universal Mobile Telecommunications System (UMTS); Multimedia Broadcast/Multicast Service (MBMS); UTRAN/GERAN requirements (3GPP TR 25.992)".

[29] ETSI TS 123 246: "Universal Mobile Telecommunications System (UMTS); Multimedia Broadcast/Multicast Service (MBMS); Architecture and functional description (3GPP TS 23.246)".

[30] ITU-R Recommendation SM.1541: "Unwanted emissions in the out-of-band domain".

[31] ITU-R Recommendation M.1142: "Sharing in the 1-3 GHz frequency range between geostationary space stations operating in the mobile-satellite service and the fixed service".

[32] ERC Report 65: "Adjacent band compatibility between UMTS and other services in the 2 GHz band".

[33] EU FP5 R&D Satin project, Deliverable 5 (D5): "S-UMTS Packet-based Layer 1 & 2 Functions".

[34] EU FP5 R&D Satin project, Deliverable 7 (D7): "Evaluations and Recommendation".

[35] Satin publication: "Initial synchronization procedure in S-UMTS networks for multimedia broadcast multicast services".

[36] Satin publication: "Cell search procedure in S-UMTS networks".

[37] ECC PT1 (03)79: "Sharing and compatibility studies between the satellite and terrestrial components of IMT-2000 in the 2.5 GHz range (continuation)".

[38] ECC PT1 (02)024: "First results of sharing and adjacent band compatibility studies between the terrestrial and satellite components of IMT-2000 in the 2.5 GHz range (continuation)".

[39] ITU 8F/862-E: "Parameters of a satellite based digital multimedia broadcasting (S-DMB) system to be used in compatibility studies between the terrestrial and the satellite component of IMT-2000".

[40] UMTS TR 30.20: "Universal Mobile Telecommunications System (UMTS); Technical characteristics, capabilities and limitations of mobile satellite systems applicable to the UMTS".

[41] ICAP 91, Seventh International Conference on (IEE): "Aeronautical Mobile Satellite Communication propagation characteristics in flight experiment using ETS-V".

[42] ITU-T Recommendation G.726: "40, 32, 24, 16 kbit/s adaptive differential pulse code modulation (ADPCM)".

[43] ETSI TS 101 851-1: "Satellite Earth Stations and Systems (SES); Satellite Component of UMTS/IMT2000; G-family; Part 1: Physical channels and mapping of transport channels into physical channels (S-UMTS-A 25.211)".

[44] ETSI TS 101 851-2: "Satellite Earth Stations and Systems (SES); Satellite Component of UMTS/IMT2000; G-family; Part 2: Multiplexing and channel coding (S-UMTS-A 25.212)".

[45] ETSI TS 101 851-3: "Satellite Earth Stations and Systems (SES); Satellite Component of UMTS/IMT2000; G-family; Part 3: Spreading and modulation (S-UMTS-A 25.213)".

[46] ETSI TS 101 851-4: "Satellite Earth Stations and Systems (SES); Satellite Component of UMTS/IMT2000; G-family; Part 4: Physical layer procedures (S-UMTS-A 25.214)".

3 Definitions, symbols and abbreviations

3.1 Definitions

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

cell: geographical area under Intermediate Module Repeater (IMR) coverage

handover: process in which the User Equipment (UE) continuously receives services while it crosses radio access areas covered with distinct radio access mode and/or radio system

rice factor: power ratio between LOS component and diffuse component

spot: geographical area under beam coverage

3.2 Symbols

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

$\frac{S-CCPCH\_E_c}{I_{or}}$ ratio of the transmit energy per PN chip of the S-CCPCH to the total transmit power spectral density at the Node B antenna connector.

$\frac{E_b}{N_t}$ ratio of combined received energy per information bit to the effective noise power spectral density for the P-CCPCH and S-CCPCH at the UE antenna connector. Following items are calculated as overhead: pilot, TPC, TFCI, CRC, tail, repetition, convolution coding and Turbo coding.

C_p Primary synchronization code.

I_{oc}	power spectral density of a band limited white noise source (simulating interference from spots, which are not defined in a test procedure) as measured at the UE antenna connector.
$\hat{I}_{or}$	received power spectral density of the downlink as measured at the UE antenna connector.

3.3 Abbreviations

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

ACLR	Adjacent Channel Leakage Ratio
AWGN	Additive White Gaussian Noise
BCCH	Broadcast Control CHannel
BCH	Broadcast CHannel
BLER	BLock Error Ratio
BMC	Broadcast/Multicast Control
BS	Base Station
CCCH	Common Control CHannel
CCPCH	Common Control Physical CHannel
CCTrCH	Code Composite Transport CHannel
CDMA	Code Division Multiple Access
C/I	Carrier to Interference
CPICH	Common Pilot CHannel
CRC	Cyclic Redundancy Check
CTCH	Common Traffic CHannel
DL	DownLink
DS	Direct Sequence
DTX	Discontinuous Transmission
EIRP	Effective Isotropic Radiated Power
FACH	Forward Access CHannel
FDD	Frequency Duplex Division
FDM	Frequency Division Multiplex
FEC	Forward Error Correction
FSS	Fixed Satellite Service
GEO	Geostationary Earth Orbit
GMR	GEO Mobile Radio
GSM	Global System for Mobile communications
HDFSS	High Density Fixed Satellite Service
HEO	Highly-inclined Elliptical Orbit
IMR	Intermediate Module Repeater
LEO	Low Earth ORBIT
LHCP	Left-Hand Circular Polarisation
LOS	Line Of Sight
MAC	Medium Access Control
MBMS	Multimedia Broadcast Multicast Service
MCCH	MBMS Control CHannel
Mcps	Mega chip per second
MEO	Medium Earth Orbit
MICH	MBMS Indicator CHannel
MSS	Mobile Satellite Service
MTCH	MBMS Traffic CHannel
MUD	Multi User Detection
NCCH	Notification Common Control CHannel
NLOS	No Line Of Sight
OVSF	Orthogonal Variable Spreading Factor
PCCC	Parallel Concatenated Convolutional Code
PCCH	Paging Control CHannel
P-CCPCH	Primary Common Control Physical CHannel
PCH	Paging CHannel
P-CPICH	Primary Common Pilot CHannel
PDA	Personal Digital Assistant
PDCP	Packet Data Convergence Protocol
PHY	PHYsical (layer)

PI	Paging Indicator
PICH	Paging Indicator CHannel
PN	Personal Numbering
PSC	Primary Synchronization Code
RF	Radio Frequency
RHCP	Right-Hand Circular Polarisation
RLC	Radio Link Control
RNC	Radio Network Controller
RNS	Radio Network Subsystem
RRC	Radio Resource Control
SAP	Satellite Access Point
S-CCPCH	Secondary Common Control Physical CHannel
SCH	Synchronization CHannel
S-CPICH	Secondary-Common Pilot CHannel
SFN	System Frame Number
S-MBMS	Satellite-Multimedia Broadcast/Multicast Service
SRI	Satellite-Radio Interface
SSC	Secondary Synchronization Code
TDD	Time Division Duplex
TFCI	Transport Format Combination Indicator
TPC	Transmit Power Control
TrCH	Transport CHannel
TFS	Transport Format Set
TTI	Time Transmission Interval
T-UMTS	Terrestrial-UMTS
UE	User Equipment
UL	UpLink
UMTS	Universal Mobile Telecommunication System
USRAN	UMTS Satellite Radio Access Network
UTRA	UMTS Terrestrial Radio Access
UTRAN	UMTS Terrestrial Radio Access Network
W-CDMA	Wideband-Code Division Multiple Access

4 Satellite Multimedia Broadcast/Multicast Service

4.1 System architecture

The proposed system architecture is devoted to Satellite Multimedia Broadcast Multicast Services (S-MBMS), as depicted in figure 4.1.

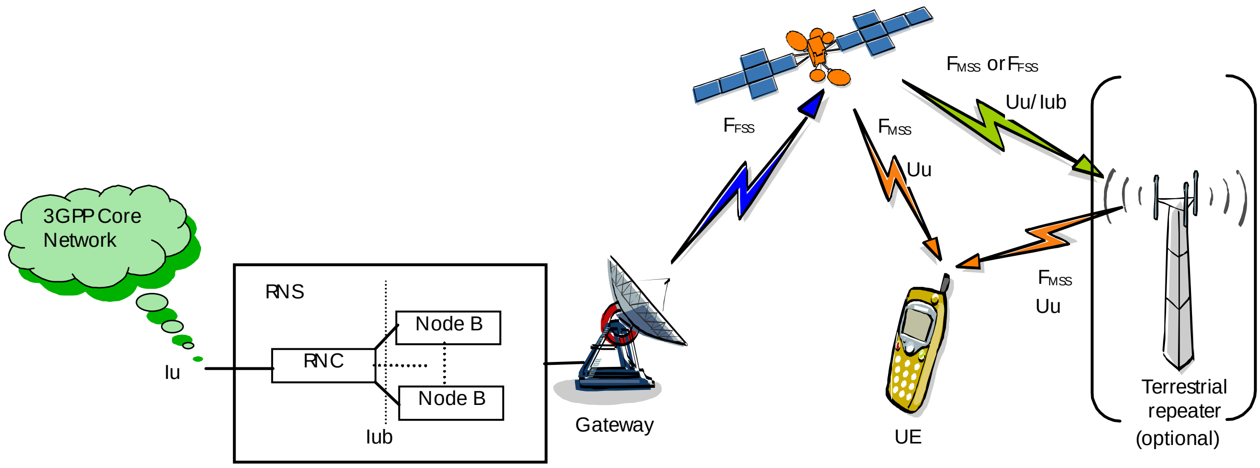


Figure 4.1: System architecture

The present document focuses on the forward link direction which is required to support the broadcast service as defined by 3GPP.

The return link required for multicast sessions interactive link may be provided either by terrestrial 2G/3G network or by a satellite return link. The provision of the return link is out of the scope of the present document.

The system may provide either single or multiple satellite constellation, each satellite may provide either mono or multi-spot coverage.

An S-MBMS area may be either a spot or a group of spots for roaming users.

User Equipment (UEs) receive S-MBMS services from one or several satellites which redirect the radio signal from gateways. The system allows for either a centralized gateway or a group of geographically dispatched gateways, depending on the operators requirements. The Gateway connects the signal from the Radio Network Subsystem (RNS), i.e. Node Bs and RNC. The decision to integrate Node Bs and/or RNC inside or outside the Gateway is under manufacturers' implementation choice.

The system addresses UEs fully compatible with S-UMTS Interface G, with adaptation for agility to the MSS (Mobile Satellite Services) frequency band.

In a satellite environment, signal transmission is subject to suffer from path blocking due to buildings, mountains, etc. In order to ensure coverage continuity in highly shadowed areas, the system can be completed with Intermediate Module Repeaters (IMRs) which role is to amplify and repeat the signal from the satellite to terrestrial coverage in the MSS frequency band. The feeding of IMRs by the satellite is made either in MSS or a Fixed Satellite Service (FSS) band. IMR's feeder link reception antenna is positioned in line of sight to the satellite.

On the system point of view, satellite and IMRs have the same functionality, which is reduced to signal repetition.

When IMRs are deployed, UEs are subject to receive S-MBMS services:

- from the satellite only (areas where IMRs are not deployed or situation with no signal view from IMRs);
- from IMRs only (situation where there is no view of the satellite signal);
- simultaneously from satellite and IMRs.

In the present document, the term "spot" applies to beam coverage area while the term "cell" applies to IMR coverage area.

4.2 Frequency bands

4.2.1 Service link

The S-MBMS frequency bands are allocated in the IMT-2000 MSS band.

For the space-to-earth direction and for the IMR signal repetition, the UE is able to receive S-MBMS in the 2 170 MHz to 2 200 MHz band, which has been allocated by WARC-92 to MSS downlink and is the "core band".

This frequency band is adjacent to the terrestrial UMTS Core frequency band, as depicted in figure 4.2. The exploitation of adjacent bands should ease 3GPP standardized UE reuse provided they are adapted for MSS frequency agility.

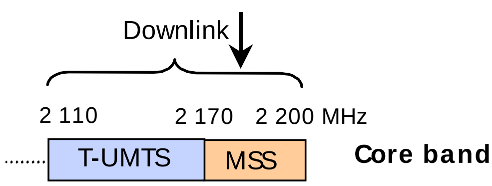


Figure 4.2: IMT-2000 spectrum allocation

4.2.2 Feeder links

The present document does not intend to specify feeder links. Nevertheless, candidate frequency bands are given for indication.

The gateway to satellite feeder link is intended to be operated in the 27,5 GHz to 30 GHz band.

Depending on the IMR configuration, the satellite to IMR link is intended to be operated either:

- "on-channel" IMR: in the service link band (2 170 MHz to 2 200 MHz). This configuration is suitable for indoor coverage;
- "non on-channel" IMR: in the HDFSS band (19,7 GHz to 20,2 GHz). This configuration is suitable for outdoor coverage.

4.3 Satellite system configuration

The system is able to cope with several satellite constellation types, i.e. LEO, HEO, MEO or GEO. It is out of the scope of the present document to restrict the satellite system configuration.

Nevertheless, in order to present realistic deployment scenario, the present document focuses on the GEO constellation type.

Several architectures are envisaged depending on throughput requirements. The examples below assume European coverage. Global beam configuration means there is a unique spot covering the entire Europe area.

Multi-beam configuration means a satellite serves several spots, for instance 1 spot per linguistic area (7 multi-beam configuration) or 1 spot per regional area (extended multi-beam configuration).

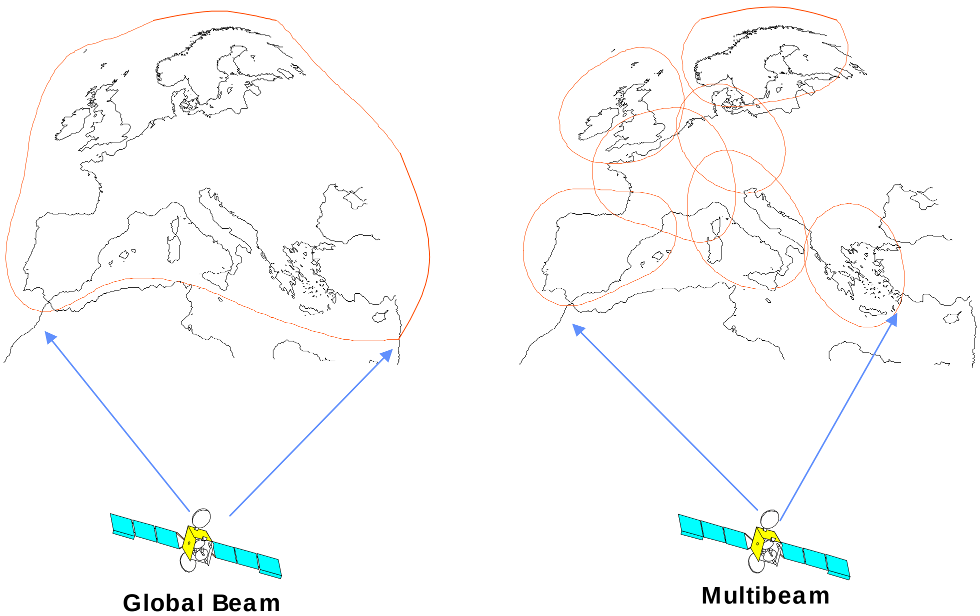


Figure 4.3: Global beam and 7 multi-beam satellite configuration

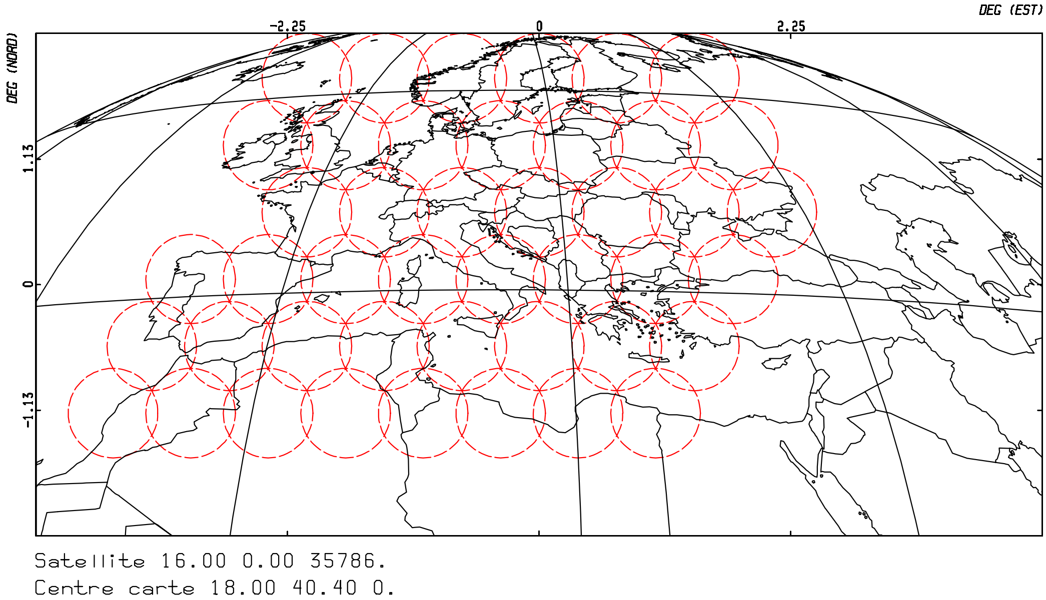


Figure 4.4: Extended multi-beam configuration

An other possible configuration is a system built with several satellites, each satellite serving several spots.

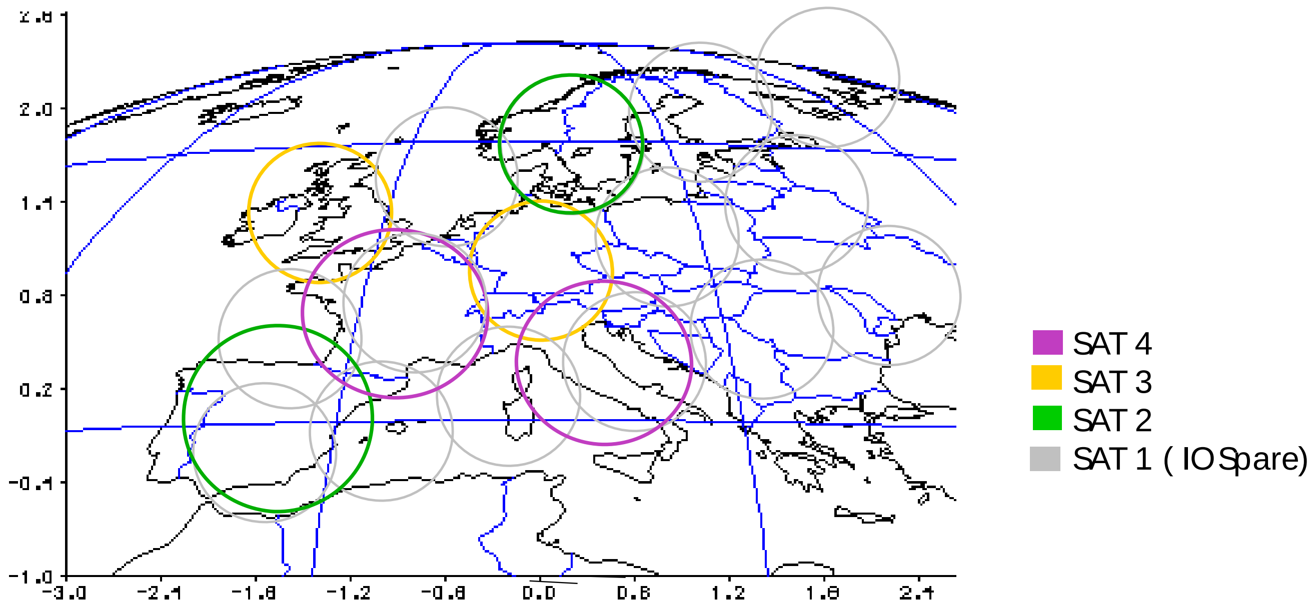


Figure 4.5: Multi-satellite and multi-beam configuration

4.3.1 Global beam architecture

The global beam architecture provides an overall throughput of 3,84 Mb/s over Europe shared among 2 FDMs, each carrying 5 channel codes at 384 kbit/s. Each FDM occupies 5 MHz bandwidth among MSS frequency band. Satellite performances are summarized in table 4.1.

Table 4.1: Satellite global beam architecture

Global beam		
Number of spot beams		1
Downlink (satellite to UE)		
Frequency (satellite to UE)	MHz	2 170 to 2 200
Polarization		LHCP or RHCP
On board EIRP per carrier	dBW	64

4.3.2 Multi-beam architecture

Satellite performances are summarized in table 4.2.

Table 4.2: Satellite 7 multi-beam architecture

7 Multibeam		
Number of spot beams		7
Downlink (satellite to UE)		
Frequency (satellite to UE)	MHz	2 170 to 2 200
Polarization		LHCP or RHCP
On board EIRP per carrier	dBW	From 64 to 74 (see note)
NOTE: Depending on considered spot beam and frequency reuse pattern.		

4.3.3 Extended multi-beam architecture

Satellite performances are summarized in table 4.3.

Table 4.3: Satellite extended multi-beam architecture

Extended Multibeam		
Number of spot beams		30
Downlink (satellite to UE)		
Frequency (satellite to UE)	MHz	2 170 to 2 200
Polarization		LHCP or RHCP
On board EIRP per carrier	dBW	From 64 to 74 (see note)
NOTE: Depending on considered spot beam.		

4.3.4 Multi-satellite/multi-beam architecture

This configuration is addressed in the present document but not fully analysed.

4.4 User Equipment

User Equipment (UE) may be of several types:

- **3G standardized handset:** the use in satellite environment requires adaptation for frequency agility to the MSS band. The basic assumption is UE equipped with standard omni-directional antenna (e.g. antenna gain: 0 dBi). While satellite antenna polarization is circular, handset suffers from 3 dB polarization loss.
- **Handheld:** the handheld configuration is built with a PDA to which an external antenna may be appended.
- **Vehicular:** the vehicular configuration is obtained by mounting an RF module on car roof connected to the UE in the cockpit.
- **Transportable:** the transportable configuration is built with a notebook which cover contains flat patch antennas (manually pointed towards the satellite).
- **Aeronautical:** aeronautical configuration is built by mounting an antenna on top of the fuselage.

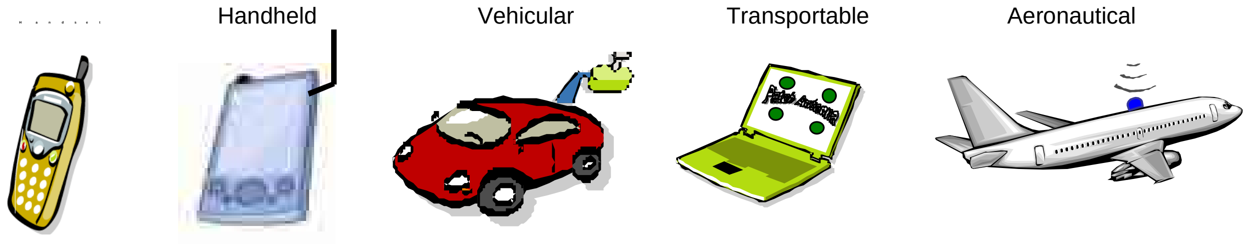


Figure 4.6: UE configurations

The gain characteristics are summarized in table 4.4.

Table 4.4: UE maximum antenna gain (typical values)

UE type	Ref. Antenna Gain	Receiver noise figure	System temp.			G/T		
			Rural	Sub-urban	Urban	Rural	Sub-urban	Urban
3G Handset	0 dBi	4,5 dB	817,3 K			-29,1 dB/K		
Handheld	1 dBi	4,5 dB	727,3 K		817,3 K	-27,6 dB/K		-28,1 dB/K
Vehicular	4 dBi	2 dB		488,6 K	578,6 K	-22,4 dB/K	-22,9 dB/K	-23,6 dB/K
Vehicular	4 dBi	2 dB	320 K	370 K	460 K	-21 dB/K	-21,7 dB/K	-22,6 dB/K
Transportable	14 dBi	2 dB	320 K	370 K	460 K	-11 dB/K	-11,7 dB/K	-12,6 dB/K
Aeronautical	3 dBi	2 dB	320 K	NA	NA	-22 dB/K	NA	NA
NOTE: System temperatures are calculated with the assumption of antenna temperature equal to 150 K in rural areas, 200 K in sub-urban areas, 290 K in urban areas, while the ambient temperature is 290 K.								

4.5 Intermediate Module Repeaters (IMR)

Two kinds of architecture can be envisaged:

- "on channel" repeaters: use the same band for signal reception and retransmission. The gain is limited to around 80 dB to avoid self-oscillation and offer narrow coverage;
- "non on-channel" repeaters: use different frequency bands for signal reception and retransmission. They enable to achieve wider coverage than on-channel repeaters, but require an additional frequency band for feeding (e.g. HDFSS band).

Low-cost and low-power IMRs can be easily collocated to terrestrial UTRAN Node B sites to provide the same coverage. They can also reuse some Node B subsystems (e.g. sectored antennas) since frequency bands for both satellite and terrestrial components of IMT-2000 are adjacent.

IMRs RF performance are summarized in table 4.5.

Table 4.5: IMR - RF performance

Transmit frequency (MHz)	2 170 to 2 200
Transmit polarization	Vertical
Overall EIRP (dBW)	Same as 3GPP Node B
Coverage area (°)	Up to 360° (i.e. 120° per sector)

5 W-CDMA Satellite Radio Interface (SRI)

Clause 5 gives a description of W-CDMA as applicable to the S-MBMS satellite environment.

5.1 General description

5.1.1 S-UMTS Interface G key features for satellite MBMS

Listed below are the key services and operational features of the S-UMTS Interface G radio-interface:

- support of 3GPP standard MBMS services from low-data-rate (8 kbps) up to high-data-rate transmission (384 kbps) with wide-area coverage;
- high service flexibility with support of multiple parallel variable-rate services;
- built-in support for future capacity/coverage-enhancing technologies, such as adaptive antennas, advanced receiver structures, and satellite diversity;
- support of inter-frequency handover for operation with hierarchical cell structures and handover to other systems.

5.1.2 Key technical characteristics

Key technical characteristics are summarized in table 5.1.

Table 5.1: Key technical characteristics

Multiple-Access scheme	DS-CDMA
Duplex scheme	FDD
Chip rate	3,840 Mcps
Carrier spacing	5 MHz (200 kHz carrier raster)
Frame length	10 ms
Inter-spot synchronization	No accurate synchronization needed
Multi-rate/Variable-rate scheme	Variable-spreading factor + Multi-code
Channel coding scheme	Convolutional coding (rate 1/2 - 1/3) Turbo coding 1/3
Packet access	Mono mode (common channel)

5.1.3 Radio interface protocol architecture

Radio interface protocol stack is extracted from 3GPP UTRAN (see [14]).

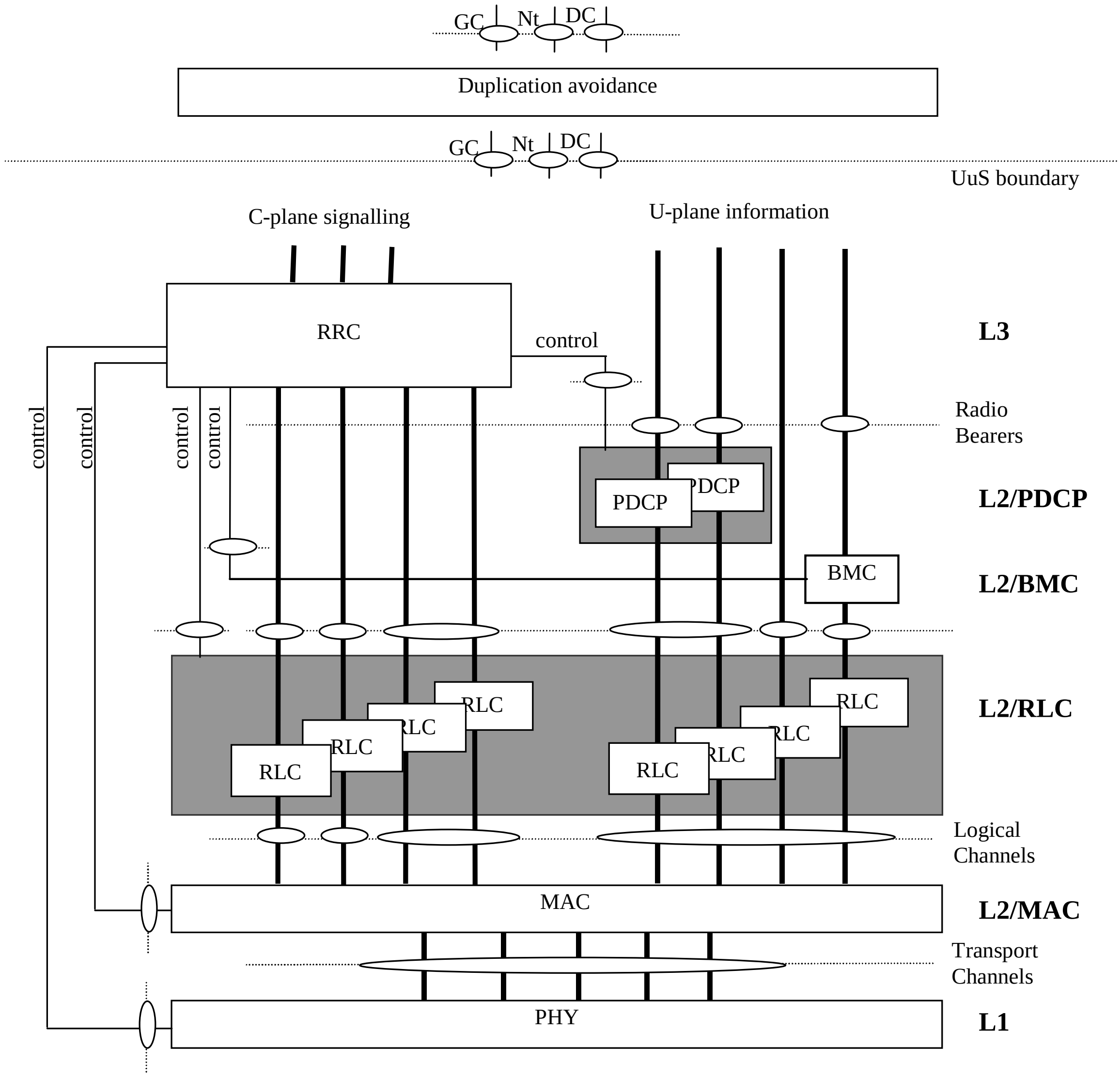


Figure 5.1: Radio interface protocol architecture

5.2 Channel structure

The channel structure is the same as in 3GPP (see [14]). It is described here for clarification, reduced to common channels required for S-MBMS services.

The MBMS channels are still under definition in 3GPP. Any change may impact clause 5.2.

5.2.1 Logical channels

All the logical channels are downlink only and point-to-multipoint. The following common logical channels are defined (see [14]):

- Broadcast Control Channel (BCCH): used to broadcast system- and spot-specific information. The BCCH is always transmitted over the entire spot;
- Paging Control Channel (PCCH): used to carry control information to UEs. The PCCH is always transmitted over the entire spot;

- Common Control Channel (CCCH): for transmitting control information to UEs;
- MBMS Control Channel (MCCH): for transfer of control information related to MBMS services to UEs;
- MBMS Traffic Channel (MTCH): for transfer of MBMS traffic;
- MBMS Scheduling Channel (MSCH): for transmission of S-MBMS service transmission schedule. The control plane information on MSCH is S-MBMS service and S-MBMS physical channel specific;
- Notifications Common Control Channel (NCCH): for transfer of notifications. This channel may replace MCCH in case only notifications would be required for control information.

5.2.2 Transport channels

Common transport channels are:

- Broadcast Channel (BCH): used for broadcast of system information into an entire spot;
- Paging Channel (PCH): used for broadcast of control information into an entire spot allowing efficient UE sleep mode procedures. Currently identified information types are paging and notification. Another use could be USRAN notification of change of BCCH information;
- Forward Access Channel (FACH): used for transmission of S-MBMS traffic and control/scheduling information.

To each transport channel, there is an associated transport format (for transport channels with a fixed or slow changing rate) or an associated Transport Format Set (TFS) (for transport channels with fast changing rate). A transport format is defined as a combination of encoding, interleaving, bit rate and mapping onto physical channels. A Transport Format Set is a set of Transport Formats.

5.2.3 Physical channels and signals

Physical channels and signals are:

- Primary Common Pilot Channel (P-CPICH): carries a pre-defined sequence of symbols. It is the phase reference for SCH, P-CCPCH, PICH and S-CCPCH. It is used by UEs for spot pilot synchronization, and downlink channels estimation;
- Secondary Common Pilot Channel (S-CPICH): optional. For hot spots service provision, i.e. operation with narrow antenna beams (either satellite or IMR antenna);
- Synchronization Channel (SCH): consists of two sub channels, the Primary and Secondary SCH. Used for cell search;
- Primary Common Control Physical Channel (P-CCPCH): carrying BCH;
- Secondary Common Control Physical Channel (S-CCPCH): carrying FACH and PCH;
- Paging Indicator Channel (PICH): associated to S-CCPCH. Indicates the frame number at with UE has to extract PCH from S-CCPCH;
- S-MBMS Indication Channel (MICH): similar to PICH, but related to S-MBMS only. A single MICH frame is able to carry indications for every service-group.

5.2.4 Logical to transport channels mapping

The mappings as seen from the UE and USRAN sides are shown in figures 5.2 and 5.3respectively.

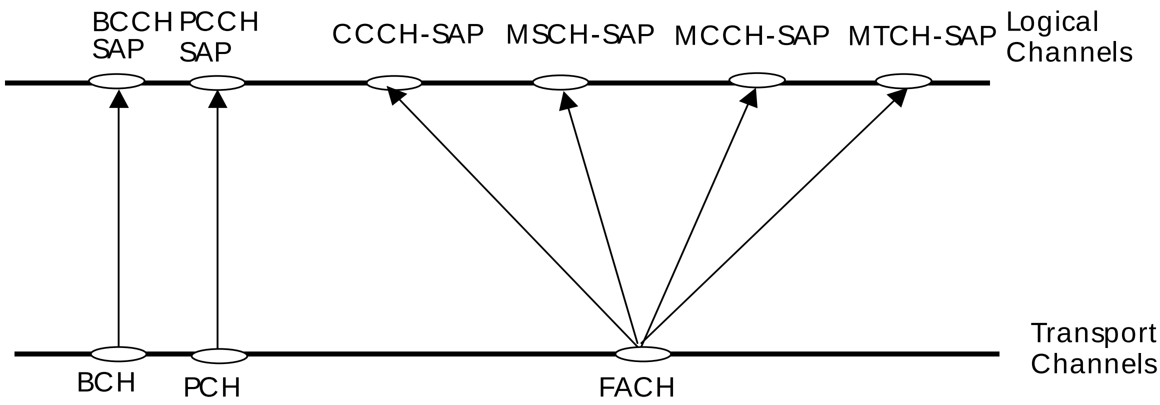


Figure 5.2: Logical channels mapped onto transport channels, seen from the UE side

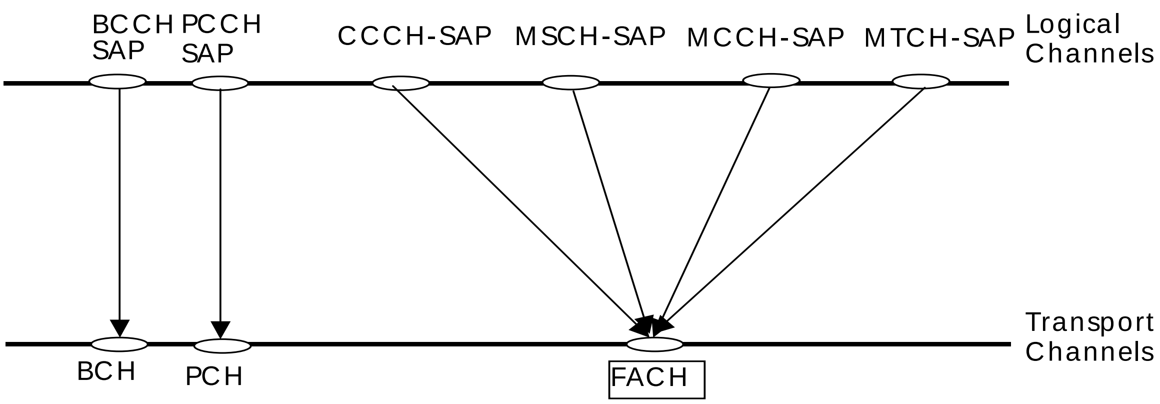


Figure 5.3: Logical channels mapped onto transport channels, seen from the USRANUSRAN side

5.2.5 Mapping and association of physical channels

Transport Channels	**Physical Channels**
	Common Pilot Channel (CPICH)
	Synchronisation Channel (SCH)
BCH	Primary Common Control Physical Channel (P-CCPCH)
FACH	Secondary Common Control Physical Channel (S-CCPCH)
PCH	Paging Indicator Channel (PICH)
	MBMS Indicator Channel (MICH)

Figure 5.4: Mapping of transport channels onto physical channels

5.3 Physical channel structure

5.3.1 Common Pilot Channel (CPICH)

The Common Pilot Channel (CPICH) is a fixed rate (30 kbps, SF=256) downlink physical channel that carries a pre-defined bit/symbol sequence.

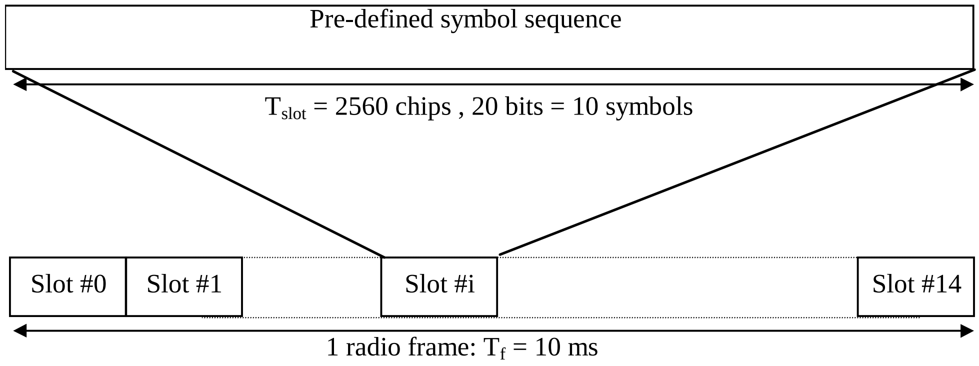


Figure 5.5: Frame structure of CPICH

There are two types of Common pilot channels, the Primary and Secondary CPICH.

5.3.1.1 Primary Common Pilot Channel (P-CPICH)

The P-CPICH characteristics are:

- the same channelization code is always used for the P-CPICH;
- the P-CPICH is scrambled by the primary scrambling code;
- there is one and only one P-CPICH per spot/cell;
- the P-CPICH is broadcast over the entire spot/cell;
- the Primary CPICH is a phase reference for the downlink physical channels.

5.3.1.2 Secondary Common Pilot Channel (S-CPICH)

The S-CPICH characteristics are:

- an arbitrary channelization code of SF=256 is used for the S-CPICH;
- a A S-CPICH is scrambled by either the primary or a secondary scrambling code;
- there may be zero, one, or several S-CPICH per spot/cell;
- a S-CPICH may be transmitted over the entire spot/cell or only over a part of the spot/cell.

5.3.2 Synchronization Channel (SCH)

The Synchronization Channel (SCH) is a downlink signal used for spot/cell search. The SCH consists of two sub-channels, the Primary and Secondary SCH. The 10 ms radio frames of the Primary and Secondary SCH are divided into 15 slots, each of length 2 560 chips.

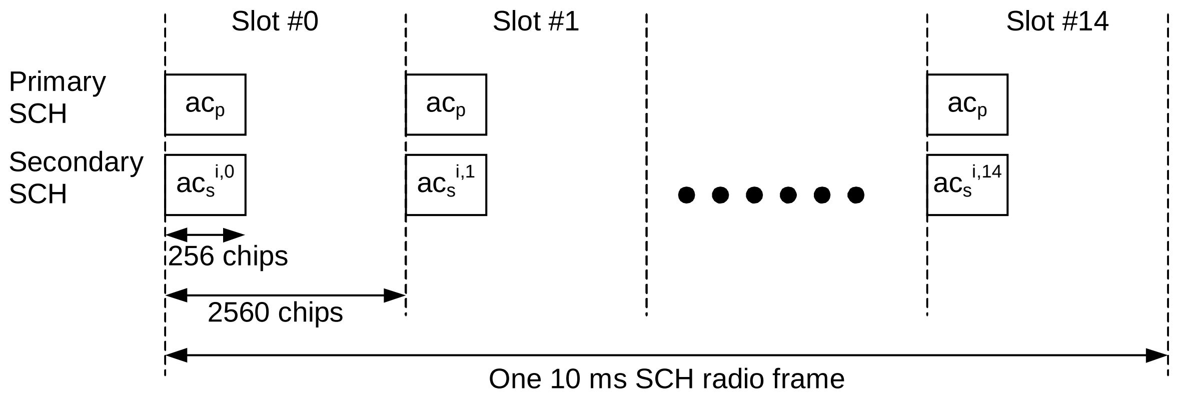


Figure 5.6: Structure of SCH

The Primary SCH consists of a modulated code of length 256 chips, the Primary Synchronization Code (PSC) denoted c_p in figure 5.6, transmitted once every slot. The PSC is the same for every spot in the system.

The Secondary SCH consists of repeatedly transmitting a length 15 sequence of modulated codes of length 256 chips, the Secondary Synchronization Codes (SSC), transmitted in parallel with the Primary SCH. The SSC is denoted $c_s^{i,k}$ in figure5.6, where i = 0, 1 to 63 is the number of the scrambling code group, and k = 0, 1 to 14 is the slot number. Each SSC is chosen from a set of 16 different codes of length 256. This sequence on the Secondary SCH indicates which of the code groups the spot's downlink scrambling code belongs to.

5.3.3 Primary Common Control Physical Channel (P-CCPCH)

The Primary CCPCH is a fixed rate (30 kbps, SF=256) downlink physical channels used to carry the BCH transport channel.

The Primary CCPCH is not transmitted during the first 256 chips of each slot. Instead, Primary SCH and Secondary SCH are transmitted during this period.

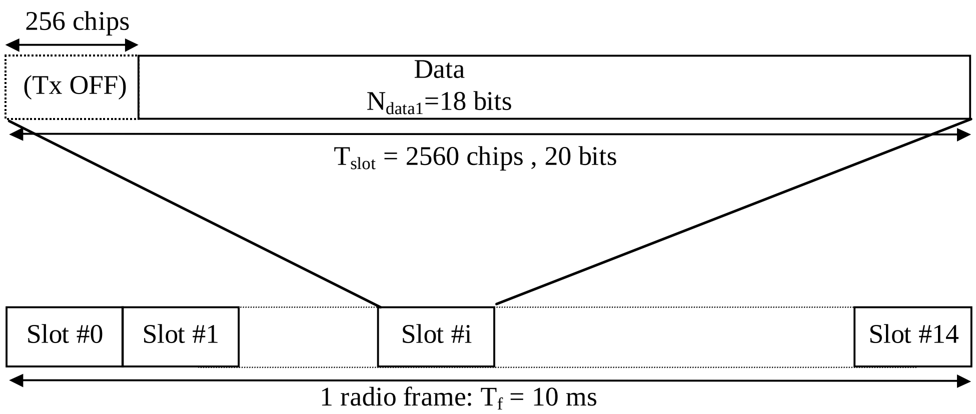


Figure 5.7: Frame structure of P-CCPCH

5.3.4 Secondary Common Control Physical Channel (S-CCPCH)

The Secondary CCPCH is used to carry the FACH and PCH. There are two types of Secondary CCPCH: those that include TFCI and those that do not include TFCI.

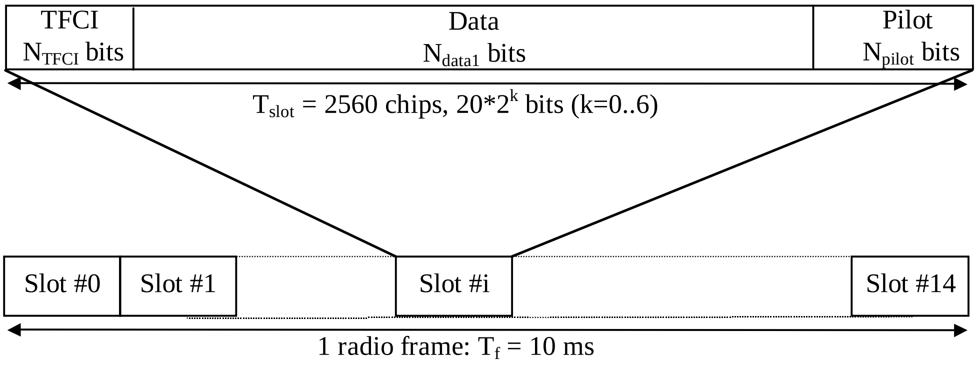


Figure 5.8: Frame structure of S-CCPCH

The parameter k in figure 5.8 determines the total number of bits per S-CCPCH slot. It is related to the spreading factor SF of the physical channel as $SF = 256/2^k$. The spreading factor range is from 256 down to 4.

The FACH and PCH can be mapped to the same or to separate S-CCPCHs. If FACH and PCH are mapped to the same Secondary CCPCH, they can be mapped to the same frame. S-CCPCH supports multiple transport format combinations using TFCI.

Table 5.2: S-CCPCH slot formats

Slot Format #i	Channel Bit Rate (kbps)	Channel Symbol Rate (ksps)	SF	Bits/Frame	Bits/ Slot	N_{data1}	N_{pilot}	N_{TFCI}
0	30	15	256	300	20	20	0	0
1	30	15	256	300	20	12	8	0
2	30	15	256	300	20	18	0	2
3	30	15	256	300	20	10	8	2
4	60	30	128	600	40	40	0	0
5	60	30	128	600	40	32	8	0
6	60	30	128	600	40	38	0	2
7	60	30	128	600	40	30	8	2
8	120	60	64	1 200	80	72	0	8
9	120	60	64	1 200	80	64	8	8
10	240	120	32	2 400	160	152	0	8
11	240	120	32	2 400	160	144	8	8
12	480	240	16	4 800	320	312	0	8
13	480	240	16	4 800	320	296	16	8
14	960	480	8	9 600	640	632	0	8
15	960	480	8	9 600	640	616	16	8
16	1 920	960	4	19 200	1 280	1 272	0	8
17	1 920	960	4	19 200	1 280	1 256	16	8
NOTE: The pilot symbol pattern is as specified in [7].								

5.3.5 Paging Indicator Channel (PICH)

The Paging Indicator Channel (PICH) is a fixed rate (SF=256) physical channel used to carry the paging indicators. The PICH is always associated with an S-CCPCH to which a PCH transport channel is mapped.

One PICH radio frame of length 10 ms consists of 300 bits. Of these, 288 bits are used to carry paging indicators. The remaining 12 bits are not formally part of the PICH and are not transmitted. The part of the frame with no transmission is reserved for possible future use.

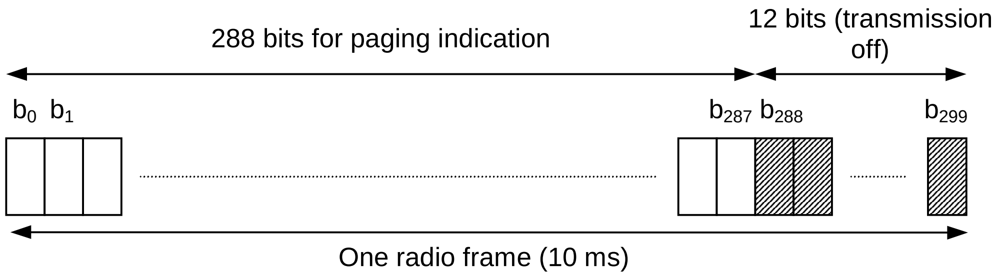


Figure 5.9: Structure of PICH

In each PICH frame, Np paging indicators $\{P_0$ to $P_{Np-1}\}$ are transmitted, where Np=18, 36, 72, or 144.

The PI is associated to the paging indicator P_q, where q is computed as a function of the PI computed by higher layers, the SFN of the P-CCPCH radio frame during which the start of the PICH radio frame occurs, and the number of paging indicators per frame (Np):

$$q = \left(PI + \left\lfloor \left((18 \times (SFN + \lfloor SFN/8 \rfloor + \lfloor SFN/64 \rfloor + \lfloor SFN/512 \rfloor)) \bmod 144 \right) \times \frac{Np}{144} \right\rfloor \right) \bmod Np$$

Further, the PI calculated by higher layers is associated with the value of the paging indicator P_q. If a paging indicator in a certain frame is set to "1" it is an indication that UEs associated with this paging indicator and PI should read the corresponding frame of the associated S-CCPCH.

The PI bitmap in the PCH data frames over Iub contains indication values for all higher layer PI values possible. Each bit in the bitmap indicates if the paging indicator associated with that particular PI may be set to 0 or 1. Hence, the calculation in the formula above is to be performed in Node B to make the association between PI and P_q.

The mapping from $\{P_0$ to $P_{Np-1}\}$ to the PICH bits $\{b_0$ to $b_{287}\}$ are according to table 5.3.

Table 5.3: Mapping of paging indicators P_q to PICH bits

Number of paging indicators per frame (Np)	$P_q = 1$	$P_q = 0$
Np=18	$\{b_{16q}, \ldots, b_{16q+15}\} = \{1, 1,\ldots, 1\}$	$\{b_{16q}, \ldots, b_{16q+15}\} = \{0, 0,\ldots, 0\}$
Np=36	$\{b_{8q}, \ldots, b_{8q+7}\} = \{1, 1,\ldots, 1\}$	$\{b_{8q}, \ldots, b_{8q+7}\} = \{0, 0,\ldots, 0\}$
Np=72	$\{b_{4q}, \ldots, b_{4q+3}\} = \{1, 1,\ldots, 1\}$	$\{b_{4q}, \ldots, b_{4q+3}\} = \{0, 0,\ldots, 0\}$
Np=144	$\{b_{2q}, b_{2q+1}\} = \{1, 1\}$	$\{b_{2q}, b_{2q+1}\} = \{0, 0\}$

5.3.6 MBMS Indicator Channel (MICH)

The MBMS Indicator Channel (MICH) is a fixed rate (SF=256) physical channel used to carry the MBMS notification indicators. The MICH is always associated with an S-CCPCH to which a FACH transport channel is mapped.

Figure 5.10 illustrates the frame structure of the MICH. One MICH radio frame of length 10 ms consists of 300 bits (b_0, b_1 to b_{299}). Of these, 288 bits (b_0, b_1 to b_{287}) are used to carry notification indicators. The remaining 12 bits are not formally part of the MICH and may not be transmitted (DTX).

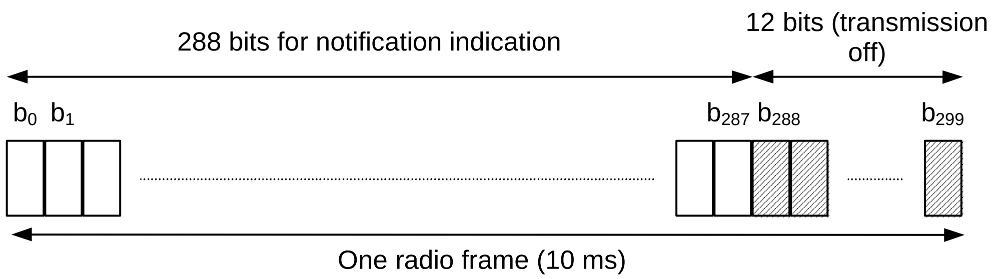


Figure 5.10: Structure of MBMS Indicator Channel (MICH)

In each MICH frame, Nn notification indicators $\{N_0$ to $N_{Nn-1}\}$ are transmitted, where Nn=18, 36, 72, or 144.

The set of NI calculated by higher layers, is associated to a set of notification indicators N_q, where q is computed as a function of the NI computed by higher layers, the SFN of the P-CCPCH radio frame during which the start of the MICH radio frame occurs, and the number of notification indicators per frame (Nn):

$$q = \left\lfloor \left(\left(C \times \left(\mathrm{NI} \oplus \left((C \times SFN) \bmod G \right) \right) \right) \bmod G \right) \times \frac{Nn}{G} \right\rfloor$$

where G = 2^{16} and C = 25033.

The set of NI signalled over Iub indicates all higher layer NI values for which the notification indicator on MICH should be set to 1 during the corresponding modification period; all other indicators may be set to 0. Hence, the calculation in the formula above may be performed in the Node B every MICH frame to make the association between NI and N_q.

The mapping from $\{N_0$ to $N_{Nn-1}\}$ to the MICH bits $\{b_0$ to $b_{287}\}$ are according to table 5.4.

Table 5.4: Mapping of paging indicators N_q to MICH bits

Number of notification indicators per frame (Nn)	$N_q = 1$	$N_q = 0$
Nn=18	$\{b_{16q}, \ldots, b_{16q+15}\} = \{1, 1, \ldots, 1\}$	$\{b_{16q}, \ldots, b_{16q+15}\} = \{0, 0, \ldots, 0\}$
Nn=36	$\{b_{8q}, \ldots, b_{8q+7}\} = \{1, 1, \ldots, 1\}$	$\{b_{8q}, \ldots, b_{8q+7}\} = \{0, 0, \ldots, 0\}$
Nn=72	$\{b_{4q}, \ldots, b_{4q+3}\} = \{1, 1, \ldots, 1\}$	$\{b_{4q}, \ldots, b_{4q+3}\} = \{0, 0, \ldots, 0\}$
Nn=144	$\{b_{2q}, b_{2q+1}\} = \{1, 1\}$	$\{b_{2q}, b_{2q+1}\} = \{0, 0\}$

5.3.7 Code allocation

5.3.7.1 Scrambling codes

The downlink scrambling code c_{scramb} is a 38 400 chips (10 ms) segment of a length $2^{18} - 1$ Gold code repeated in each frame. The scrambling codes are divided into 512 sets each of a primary scrambling code and 15 secondary scrambling codes.

The primary scrambling codes consist of scrambling codes $n = 16 \times i$ where i=0 to 511. The i:th set of secondary scrambling codes consists of scrambling codes $16 \times i + k$, where k = 1 to 15.

There is a one-to-one mapping between each primary scrambling code and 15 secondary scrambling codes in a set such that i:th primary scrambling code corresponds to i:th set of secondary scrambling codes.

Hence, according to the above, scrambling codes k = 0, 1 to 8 191 are used.

The set of primary scrambling codes is further divided into 64 scrambling code groups, each consisting of 8 primary scrambling codes. The j:th scrambling code group consists of primary scrambling codes $16 \times 8 \times j + 16 \times k$, where j = 0 to 63 and k = 0 to 7.

Each spot/cell is allocated one and only one primary scrambling code. The P-CPICH, PICH, P-CCPCH and S-CCPCH carrying PCH are always transmitted using the primary scrambling code. S-CCPCH carrying FACH can be transmitted with either the primary scrambling code or a secondary scrambling code from the set associated with the primary scrambling code of the cell.

A grouping of the downlink codes is done in order to facilitate a fast spot/cell search.

5.3.7.2 Synchronization codes

The same synchronization codes as specified in reference [9].

5.3.7.3 Channelization codes

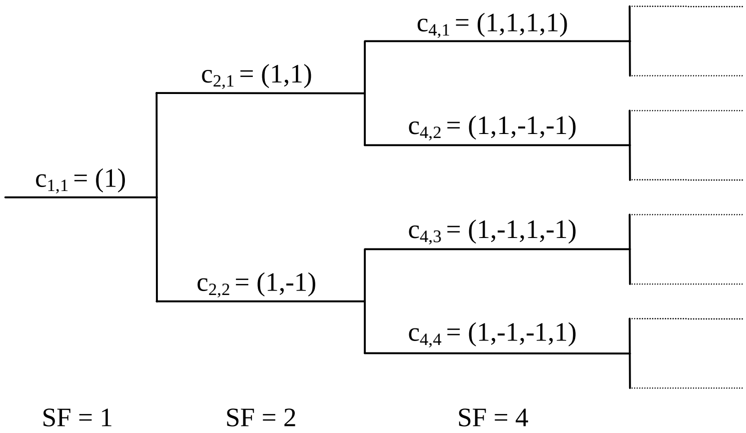


Figure 5.11: Code-tree for generation of OVSF codes

The channelization codes are Orthogonal Variable Spreading Factor (OVSF) codes that preserve the orthogonality between downlink channels of different rates and spreading factors. The OVSF codes can be defined using the code tree of figure 5.12.

Each level in the code tree defines channelization codes of length SF, corresponding to a spreading factor of SF. All codes within the code tree cannot be used simultaneously within one spot/cell. A code can be used in a spot/cell if and only if no other code on the path from the specific code to the root of the tree or in the sub-tree below the specific code is used in the same spot/cell. This means that the number of available channelization codes is not fixed but depends on the rate and spreading factor of each physical channel.

The channelization code for P-CPICH is fixed to $C_{ch,256,0}$.

The channelization code for P-CCPCH is fixed to $C_{ch,256,1}$.

The channelization codes for other physical channels are assigned dynamically by USRAN.

5.4 Channel coding and service multiplexing

5.4.1 Channel coding/interleaving for user services

W-CDMA offers three basic service classes with respect to forward-error-correction (FEC) coding (see [8]):

- standard-services with convolutional coding;
- high-quality services with Turbo coding;
- services with service-specific coding, i.e. services for which the W-CDMA layer 1 does not apply any pre-specified channel coding.

Data arrive to the coding/multiplexing unit in form of transport block sets once every transmission time interval. The transmission time interval is transport-channel specific from the set {10 ms, 20 ms, 40 ms, and 80 ms}.

The following coding/multiplexing steps are defined (see [8]):

- add CRC to each transport block;
- transport block concatenation and code block segmentation;
- channel coding;
- radio frame equalization;
- rate matching;
- insertion of Discontinuous Transmission (DTX) indication bits;
- interleaving (two steps);
- radio frame segmentation;
- multiplexing of transport channels;
- physical channel segmentation;
- mapping to physical channels.

5.4.1.1 CRC attachment

Error detection is provided on transport blocks through a Cyclic Redundancy Check (CRC). The size of the CRC is 0, 8, 16 or 24 bits.

5.4.1.2 Transport block concatenation and code block segmentation

All transport blocks in a TTI are serially concatenated. If the number of bits in a TTI is larger than *Z*, the maximum size of a code block in question, then code block segmentation is performed after the concatenation of the transport blocks. The maximum size of the code blocks depends on whether convolutional coding, turbo coding or no coding is used.

5.4.1.3 Channel coding

The scheme of Turbo coder is a Parallel Concatenated Convolutional Code (PCCC) with two 8-state constituent encoders and one Turbo code internal interleaver.

Table 5.5: Channel coding scheme and coding rate

Type of TrCH	Coding scheme	Coding rate
BCH	Convolutional coding	1/2
PCH	Convolutional coding	1/2
FACH	Convolutional coding Turbo coding No coding	1/2,1/3 1/3

5.4.1.4 Radio frame size equalization

Radio frame size equalization is padding the input bit sequence in order to ensure that the output can be segmented in data segments of same size. Radio frame size equalization is only performed in the UL.

5.4.1.5 Radio frame segmentation

When the transmission time interval is longer than 10 ms, the input bit sequence is segmented and mapped onto consecutive radio frames. Following rate matching in the DL and radio frame size equalization in the UL the input bit sequence length is guaranteed to be an integer multiple of radio frames.

5.4.1.6 TrCH multiplexing

Every 10 ms, one radio frame from each TrCH is delivered to the TrCH multiplexing. These radio frames are serially multiplexed into a coded composite transport channel (CCTrCH).

5.4.1.7 Insertion of Discontinuous Transmission (DTX) indication bits

In the downlink, DTX is used to fill up the radio frame with bits. The insertion point of DTX indication bits depends on whether fixed or flexible positions of the TrCHs in the radio frame are used. It is up to the USRAN to decide for each CCTrCH whether fixed or flexible positions are used during the connection. DTX indication bits only indicate when the transmission should be turned off, they are not transmitted.

5.4.1.8 Outer coding/interleaving

The current assumption for the outer Reed Salomon coding is a rate 4/5 code over the 2^8 - ary symbol alphabet. After outer Reed Salomon coding, symbol-wise inter-frame block interleaving is applied.

5.4.1.9 Rate matching

After channel coding and service multiplexing, the total bit rate is almost arbitrary. The rate matching matches this rate to the limited set of possible bit rates of a Dedicated Physical Data Channel. Rate matching means that bits on a transport channel are repeated or punctured.

5.5 Radio resource functions

5.5.1 Initial spot/cell search

During the initial satellite spot/cell search, the UE searches for and determines the long code and frame synchronization of the spot/cell to which it has the lowest path loss. This is carried out in three steps.

5.5.1.1 Step 1: Slot synchronization

During the first step of the initial spot/cell search procedure, the UE uses the primary synchronization channel to acquire slot synchronization to the strongest spot/cell. This is done with a matched filter matched to the primary synchronization code c_p common to all spots/cell. The output of the matched filter, accumulated over a sufficient number of slot intervals, will give peaks for each ray of each spot/cell within range of the UE. Detecting the position of the strongest peak gives the timing of the strongest spot/cell modulo the slot length.

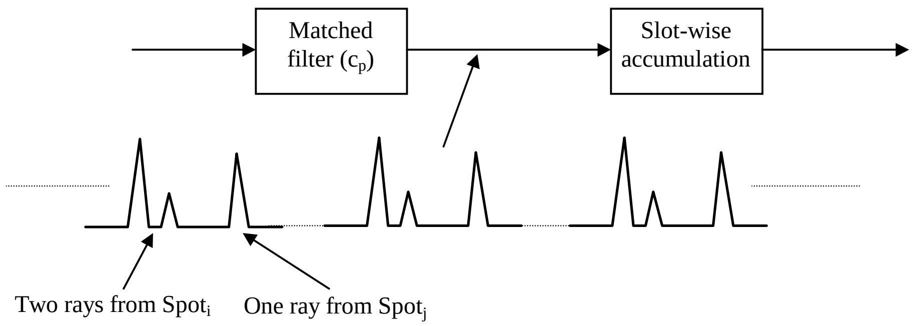


Figure 5.12: Matched-filter search for primary synchronization code

5.5.1.2 Step 2: Frame synchronization and code-group identification

During the next step of the initial spot/cell search procedure, the UE uses the secondary synchronization channel to find frame synchronization and identify the code group of the spot/cell found in the first step. This is done by correlating the received signal at the position of the secondary synchronization codes with all possible secondary synchronization codes. Note that the position of the Secondary synchronization codes are known after the first step, due to the known time offset between the primary and the secondary synchronization codes.

Furthermore, the frame synchronization is found from the modulation sequence of the secondary SCH.

5.5.1.3 Step 3: Scrambling-code identification

During the last step of the initial spot/cell search procedure, the UE determines the exact primary scrambling code used by the found spot/cell. The primary scrambling code is identified through symbol-by-symbol correlation over the CPICH with all scrambling codes within the code group identified in the second step.

After the scrambling code has been identified, the Primary CCPCH can be detected, super-frame synchronization can be acquired and the system- and spot/cell specific BCCH information can be read.

5.5.2 Radio resource allocation

5.5.2.1 Channelization codes

The channelization code for the BCCH is a predefined code which is the same for all spots/cell within the system.

The channelization code(s) used for the Secondary Common Control Physical Channel is broadcast on the BCCH.

The channelization codes for the S-CCPCH are decided by the network. The set of channelization codes may be changed during the duration of a S-MBMS service, typically as a result of a change of service or an inter-spot/cell handover. A change of downlink channelization codes is indicated to UEs on BCCH and/or PCH.

5.5.2.2 Scrambling code

The downlink scrambling code is assigned to the spot/cell at the initial deployment. The mobile station learns about the downlink scrambling code during the spot/cell search process.

5.5.2.3 IMR frequency and codes

Several radio resource allocation strategies can be adopted:

1) The first strategy, the simplest one on the point of view of resource allocation, is IMRs repeat the satellite signal as it is, i.e. on the same frequency and the same scrambling and channelization codes. IMRs are then called "'transparent IMRs". This method, as explained in clause 6.1.3 "Test environment support" results in adding artificial multi-paths. Those multi-paths delays are to be restricted to the UE rake receiver window length, which is subject to introduce tight IMR deployment constraints due to IMR signal repetition synchronization requirement together with IMR coverage area limitation thus an important number of IMRs to be deployed.

In order to soften the IMR synchronization constraints and reduce the number of IMRs to deploy, other radio resource allocation strategies can be adopted, where the satellite spot coverage is considered as an umbrella cell to IMRs cell coverage. The two types of IMRs described hereafter are called "regenerative IMRs".

2) Thus a second radio resource allocation strategy deals with IMRs satellite signal repetition on an other MSS frequency. Service continuity is ensured thanks to the UE hard handover capability. There is no IMR synchronization constraints for that type of IMR.

3) In case of carrier frequency lack, a third radio resource allocation strategy consists in IMRs satellite signal repetition on the same frequency, but with a different scrambling code. The drawback of this strategy is implementation complexity on IMR (requirement of regenerative IMR type). This drawback is counterbalanced by the important relaxing of IMR synchronization constraints. Service continuity is ensured thanks to the UE multi-code scrambling reception capability(soft-combining).

Another important point to note is the use of regenerative repeaters allow to increase radio capacity as shown in annex B.

5.5.3 Power control/balancing

The near-far effect in the satellite environment is not as influent as in terrestrial environment.

However power control has to be implemented in order not to waste system power and capacity.

Slow power level variations are due to different causes:

- satellite and UE antenna gain variations;
- shadowing;
- user speed changes;
- time varying co-channel interference.

S-MBMS is mapped to common channels, which by essence are not power controlled in line with UE radio conditions. Furthermore, due to the large coverage area (at least regional spot), it is not envisaged to implement dynamic power allocation.

Margin required for shadowing is varying with UE elevation. It is thus appropriate to balance power in order to distribute more satellite power to spot covering low elevation areas.

Power control is limited to power balancing, i.e. power is allocated on a service and geographical priority basis:

- service priority means more power is allocated to emergency or high cost services;
- geographical priority means more satellite power may be allocated to the advantage of low elevation coverage areas or also satellite power may be focused to hot spot areas.

Additionally, closed loop power control between layer 1 and RRC, at the network side, can be adjusted when gateway is equipped with a MSS receiver. In effect, assuming the gateway is under spot coverage, the MSS receiver measures interference, broadcast service quality reception, etc. Measurements are reported to RNC (RRC layer) which orders to Node B transmit power adaptation if required. Then spot transmit power is adjusted accordingly. This method allows for raw power control, which is not in line with each UE radio conditions under spot coverage, but which is an averaged estimation and takes into account interference variation due to broadcast traffic variation.

5.5.4 Handover

5.5.4.1 Intra-frequency handover

5.5.4.1.1 Selective/Soft Combining

Selective/Soft combining deals with simultaneous S-MBMS service reception over distinct scrambling codes from several spots/IMR cells and is applicable in case of either:

- intra-satellite spots coverage overlapping (single satellite system);
- inter-satellite spots coverage overlapping (multi satellites system);
- IMR deployment with scrambling code different from that of the satellite.

When in active broadcast reception mode, the UE continuously searches for new spots/cells on the current carrier frequency. This spot/cell search is carried out in basically the same way as the initial spot/cell search. The main difference compared to the initial spot/cell search is that an UE station has received a priority list from the network. This priority list describes in which order the downlink scrambling codes should be searched for and does thus significantly reduce the time and effort needed for the scrambling-code search (step 3). The priority list is continuously updated to reflect the changing neighbourhood of a moving UE.

During the search, the UE measures the received signal level broadcast from neighbouring spot/cell, compares them to a set of thresholds, and adds or removes satellite spot/IMR cell MBMS reception from its *reception set.* The *reception set* is defined as the set of spots/cells from which the same S-MBMS traffic is received, simultaneously demodulated and coherently combined.

The selective combining for S-MBMS p-t-m transmission is managed at UE RLC level and is supported by RLC PDU numbering.

Soft combining is managed at UE physical layer level. It is applicable when spots/IMR cells are synchronized in such a way that maximum delays for multiple S-CCPCH combining, i.e. latest arrival at UE receiver is within 1 TTI + 1 slot.

When selective combining or soft is available between spots/IMR cells, UE is informed by USRAN RRC signalling. Then UE determines the neighbouring spot/IMR cell suitable for selective or soft combining based on threshold (e.g. measured CPICH Ec/No).

The possibility of performing selective or soft combining is signalled to the UE.

5.5.4.1.2 Softer combining

Softer combining is the special case of a soft combining between sectors/spots belonging to the same gateway (Node B) site or the same IMR. Conceptually, a softer combining is similar to soft combining on the UE point of view.

5.5.4.2 Inter-frequency handover

Inter-frequency handover may typically occur in the following situations:

- handover between spots to which different number of carriers have been allocated, e.g. due to different capacity requirements (hot-spot scenarios);
- handover between spots of different overlapping orthogonal spot layers using different carrier frequencies;
- handover between spot and IMRs when IMRs repeat the signal on another frequency;
- handover between different operators/systems using different carrier frequencies including handover to terrestrial UMTS/GSM.

A key requirement for the support of seamless inter-frequency handover is the possibility for the UE to carry out spot search on a carrier frequency different from the current one, without affecting the ordinary data flow. W-CDMA supports inter-frequency spot search in two different ways, a dual-receiver approach and a slotted-downlink-transmission approach.

5.5.4.2.1 Dual-receiver

For a UE with receiver diversity, there is a possibility for one of the receiver branches to temporarily be reallocated from diversity reception and instead carry out reception on a different carrier, i.e. UE implements capability for simultaneous reception on distinct carriers.

5.5.4.2.2 Slotted downlink transmission

With slotted downlink transmission, it is possible for a single-receiver UE to carry out measurements on other frequencies without affecting the ordinary data flow. When in slotted mode, the information normally transmitted during a 10 ms frame is compressed in time, either by code puncturing or by reducing the spreading factor by a factor of 2. In this way, an idle time period of up to 5 ms is created within each frame. During that time, the UE receiver is idle and can be used for inter-frequency measurements.

This slotted downlink transmission may be applied periodically to all allocated S-MBMS channels.

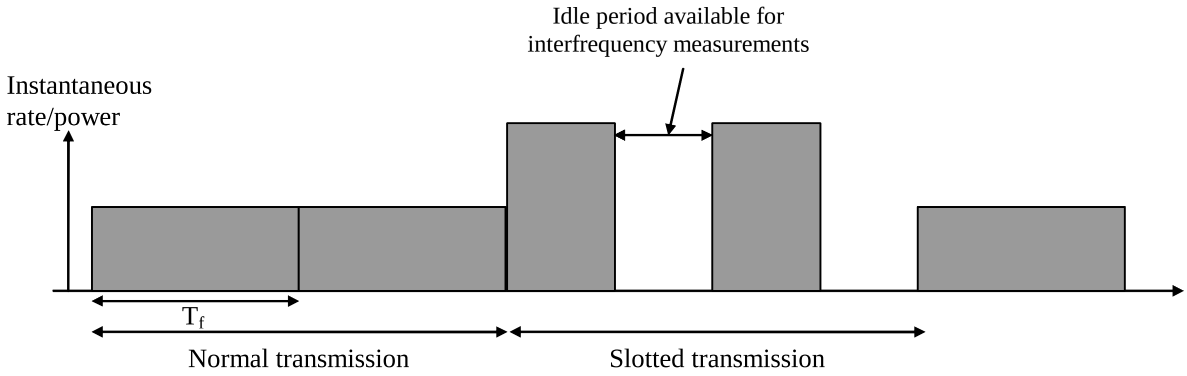


Figure 5.13 Downlink slotted transmission

5.5.5 UE energy saving optimization

Downlink slotted transmission can be used to reduce the average power consumption of UE, enabling the receiver to stay active for only a fraction of the time.

5.5.6 Support of TDD

For further release.

6 Performance requirements

6.1 Test environment support

6.1.1 Satellite environment

UEs operate in either LOS or NLOS propagation conditions, i.e. either Rice or Rayleigh propagation channel.

Path blockage can be induced by heavy shadowing from hills, tress, bridges and buildings. The car body (vehicular UE configuration) and the head of the user (handset UE configuration) can also have a non-negligible impact. Tree shadowing can lead to 10 dB to 20 dB of excess attenuation and is often the cause for link outage.

The useful dynamic range for the received signal power is much smaller than for terrestrial environments (for which it goes up to 80 dB). This is due to the different system geometry (reduced path loss variation within each satellite beam, in the order of 3 dB to 5 dB) and to the limited satellite RF power which is insufficient to counteract path blockage.

Multi-path diversity in a single satellite system results in paths in the range of -20 dB below the main path. Multi-paths are exploited by rake receiver.

In case the system is composed of more than one satellite, satellite diversity can be provided, including soft combining capability. Radio channels can benefit from this for link outage reduction and quality of service improvement.

Channel tap models from [2] are hereafter adopted.

Table 6.1: Channel model A (10 % delay spread values); Rural

Tap number	Relative tap delay value (ns)	Tap amplitude distribution	Parameter of amplitude distribution (dB)	Average amplitude with respect to free space propagation	Rice factor (dB)	Doppler spectrum
1	0	LOS: Rice NLOS: Rayleigh	10 log c 10 log P_m	0,0 -7,3	10 -	Rice Classic
2	100	Rayleigh	10 log P_m	-23,6	-	Classic
3	180	Rayleigh	10 log P_m	-28,1	-	Classic

Table 6.2: Channel model B (50 % delay spread values); Sub-urban

Tap number	Relative tap delay value (ns)	Tap amplitude distribution	Parameter of amplitude distribution (dB)	Average amplitude with respect to free space propagation	Rice factor (dB)	Doppler spectrum
1	0	LOS: Rice NLOS: Rayleigh	10 log c 10 log P_m	0,0 -9,5	7 -	Rice Classic
2	100	Rayleigh	10 log P_m	-24,1	-	Classic
3	250	Rayleigh	10 log P_m	-25,1	-	Classic

Table 6.3: Channel model C (90 % delay spread values); Urban

Tap number	Relative tap delay value (ns)	Tap amplitude distribution	Parameter of amplitude distribution (dB)	Average amplitude with respect to free space propagation	Rice factor (dB)	Doppler spectrum
1	0	LOS: Rice NLOS: Rayleigh	10 log c 10 log P_m	0,0 -12,1	3 -	Rice Classic
2	60	Rayleigh	10 log P_m	-17,0	-	Classic
3	100	Rayleigh	10 log P_m	-18,3	-	Classic
4	130	Rayleigh	10 log P_m	-19,1	-	Classic
5	250	Rayleigh	10 log P_m	-22,1	-	Classic

6.1.2 Intermediate Module Repeater environment (IMR)

When UEs are on view of IMRs only (no view of the satellite signal), radio environment is terrestrial, i.e. propagation conditions apply as they are specified by 3GPP standards.

6.1.3 Combined satellite and transparent IMR environment

When UEs are on view of both transparent IMRs and satellite signals, transparent IMRs introduce artificial multi-paths. The satellite and transparent IMR paths are to be added in the rake receiver fingers set.

Satin project proposed propagation models that apply to combined satellite and IMR environment (see [33] and [34]). They are based on two transparent IMR configurations:

- low power transparent IMR: the cell radius is 400 m;
- high power transparent IMR: the cell radius is 2 km.

In both cases, IMR taken as a reference is surrounded by 6 IMRs, with a regular hexagonal cellular layout. The distance of the UE from the reference IMR is 0,87 × cell radius. The path delay profiles extracted from reference [33] are depicted hereafter:

Table 6.4: Path delay profile; Low power transparent IMR

Sat		Ref. IMR		IMR1		IMR2	
Relative delay (µs)	Avg. power (dB)	Relative delay (µs)	Avg. power (dB)	Relative delay (µs)	Avg. power (dB)	Relative delay (µs)	Avg. power (dB)
0,00	-3,8	1,99	0,0	0,32	-3,7	2,44	-13,2
		2,30	-1,0	0,63	-4,7	2,75	-14,2
		2,70	-9,0	1,03	-12,7	3,15	-22,2
		3,08	-10,0	1,41	-13,7	3,53	-23,2
		3,72	-15,0	2,05	-18,7	4,17	-28,2
		4,50	-20,0	2,83	-23,7	4,95	-33,2
IMR3		**IMR4**		**IMR5**		**IMR6**	
Relative delay (µs)	Avg. power (dB)	Relative delay (µs)	Avg. power (dB)	Relative delay (µs)	Avg. power (dB)	Relative delay (µs)	Avg. power (dB)
5,18	-17,5	6,16	-17,5	4,41	-13,2	1,30	-3,7
5,49	-18,5	6,47	-18,5	4,72	-14,2	1,61	-4,7
5,89	-26,5	6,87	-26,5	5,12	-22,2	2,01	-12,7
6,27	-27,5	7,25	-27,5	5,50	-23,2	2,39	-13,7
6,91	-32,5	7,89	-32,5	6,14	-28,2	3,03	-18,7
7,69	-37,5	8,67	-37,5	6,92	-33,2	3,81	-23,7

Table 6.5: Path delay profile; High power transparent IMR

Sat		Ref. IMR		IMR1		IMR2	
Relative delay (µs)	Avg. power (dB)	Relative delay (µs)	Avg. power (dB)	Relative delay (µs)	Avg. power (dB)	Relative delay (µs)	Avg. power (dB)
0,00	-6,5	9,96	0,0	1,58	-3,7	1,58	-3,7
		10,27	-1,0	1,89	-4,7	1,89	-4,7
		10,67	-9,0	2,29	-12,7	2,29	-12,7
		11,05	-10,0	2,67	-13,7	2,67	-13,7
		11,69	-15,0	3,31	-18,7	3,31	-18,7
		12,47	-20,0	4,09	-23,7	4,09	-23,7
IMR3		**IMR4**		**IMR5**		**IMR6**	
Relative delay (µs)	Avg. power (dB)	Relative delay (µs)	Avg. power (dB)	Relative delay (µs)	Avg. power (dB)	Relative delay (µs)	Avg. power (dB)
25,91	-17,5	30,83	-17,5	22,04	-13,2	6,50	25,91
26,22	-18,5	31,14	-18,5	22,35	-14,2	6,81	26,22
26,62	-26,5	31,54	-26,5	22,75	-22,2	7,21	26,62
27,00	-27,5	31,92	-27,5	23,13	-23,2	7,59	27,00
27,64	-32,5	32,56	-32,5	23,77	-28,2	8,23	27,64
28,42	-37,5	33,34	-37,5	24,55	-33,2	9,01	28,42

Satin project proposed a set of propagation conditions for defining performance test cases inspired by those of 3GPP specifications, taking into account the presence of IMRs and of the direct path from satellite. The test propagation conditions extracted from reference [33] are depicted hereafter.

Table 6.6: Path delay profiles; Combined Satellite and transparent IMRs test cases

S-Case 1 speed 3km/h		S-Case 2 speed 3 km/h		S-Case 3 speed 120 km/h		S-Case 4 speed 250 km/h		S-Case 5 speed 120 km/h		S-Case 6 speed 250 km/h	
Relative delay [ns]	Average power [dB]	Relative delay [ns]	Average power [dB]	Relative delay [ns]	Average power [dB]	Relative delay [ns]	Average power [dB]	Relative delay [ns]	Average power [dB]	Relative delay [ns]	Average power [dB]
0	0	0	0	0	0	0	0	0	-3	0	-3
1 042	-10	1 042	0	260	-3	260	-3	260	-3	260	-3
		26 563	0	521	-6	521	-6	521	-9	521	-9
				781	-9	781	-9	1 042	-3	1 042	-3
								1 302	-3	1 302	-3
								1 562	-3	1 562	-3
								1 823	0	1 823	0
								2 083	0	2 083	0
NOTE: For case 5 and case 6, tap at 0 ns is Rice distributed.											

6.1.4 Aeronautical environment

Aeronautical environment is derived from [47], for a speed of 800 km/h.

Table 6.7: Channel model; Aeronautical; 800 km/h

Tap number	Relative delay (ns)	Average power (dB)	Rice factor (dB)	Doppler spectrum
1	0	0	14	Rice
2	11 500	-18	-	

6.2 Expected performances

6.2.1 Summary of test measurement services

The reference measurement channel for the 5 test services is summarized hereafter. Detailed description is given in annex A.

Table 6.8: Reference measurement channels

Parameter	FACH for MTCH					Unit
Information bit rate	8	64	128	256	384	kbps
Physical channel	15	120	240	480	480	ksps
Spreading factor	256	32	16	8	4	-
Repetition/punctering rate	-13	+7,8	+21,5	+19,4		%
Time Transmission Interval	20	20	20	10	10	ms
Type of Error Protection	Convolutional	Turbo				-
Coding Rate	1/3					-
Size of CRC	16					Bit

The CPICH must cover the entire spot area. Thus the CPICH power is adjusted in order a UE in the worst case position is able to correctly receive it. The same applies to the SCH, the P-CCPCH and the PICH.

The worst case UE position is considered as being the intersection of spots.

The required power at UE receiver input is deduced from the physical common channels characteristics defined for the reception of the 4 test services as defined in TS 134 121 [24].

Table 6.9: Power at UE receiver input; Common physical channels

Physical Channel	Ec/Îor Power	Power at UE receiver input
P-CPICH	P-CPICH_$E_c/\hat{I}_{or}$ = -10 dB	-71 dBm
P-CCPCH	P-CCPCH_$E_c/\hat{I}_{or}$ = -12 dB	-73 dBm
SCH	SCH_$E_c/\hat{I}_{or}$ = -12 dB	-73 dBm
PICH	PICH_$E_c/\hat{I}_{or}$ = -15 dB	-76 dBm

6.2.2 FACH demodulation requirements

Link level simulations have been run for the test environments and services described above in order to specify the FACH receiver performance requirements.

The tables in next clauses include margin in order to take into account effects that are not modelled in simulations (imperfect channel estimation and path search, over sampling, number of floating points, and all UE hardware margin).

The results presented apply to a Block Error Ratio (BLER) of 10^{-2}.

Table 6.10: Margin applied to FACH performance

Channel	Margin
AWGN	2 dB
Case 1, Case 2 S-Case 1, S-Case 2	2,5 dB
Case 3 to Case 6 S-Case 3 to S-Case 6	3 dB
Aeronautical	4 dB
Other channels: 3 km/h, 50 km/h 120 km/h, 250 km/h	 2,5 dB 3 dB

6.2.2.1 Demodulation in static conditions

Table 6.11: FACH parameters in static propagation conditions

Parameter	Unit	
Phase reference		P-CPICH
$\hat{I}_{or}/I_{oc}$	dB	-1
I_{oc}	dBm/3,84 MHz	-60

Table 6.12: FACH requirements in static propagation conditions

Data rate	$\frac{S-CCPCH\_E_c}{I_{or}}$	$\frac{E_b}{N_t}$
8 kbps	-19,6 dB	6,3 dB
64 kbps	-12,8 dB	4 dB
128 kbps	-10,3 dB	3,4 dB
256 kbps	-7,5 dB	3,2 dB
384 kbps	-5,3 dB	3,7 dB

6.2.2.2 Demodulation in ITU Channel model A conditions

The average $\frac{S-CCPCH\_E_c}{I_{or}}$ power ratio is specified for 2 UE locations: 20 % around spot centre and spot borders.

Empty compartments mean the service is not reachable (situations suffering from too high adjacent-spot interference).

Table 6.13: FACH parameters in ITU channel model A conditions

Parameter	Unit	Test 1	Test 2
Phase reference		P-CPICH	
$\hat{I}_{or}/I_{oc}$	dB	9	-3
I_{oc}	dBm/3,84 MHz	-60	
Information Data Rate	kbps	20 % spot centre	Spot border

Table 6.14: FACH requirements in ITU channel model A conditions

Data rate	Speed	$\frac{S-CCPCH\_E_c}{I_{or}}$						$\frac{E_b}{N_t}$		
		$\frac{\hat{I}_{or}}{I_{oc}} = 9dB$			$\frac{\hat{I}_{or}}{I_{oc}} = -3dB$					
		LOS	/	*NLOS*	LOS	/	*NLOS*	LOS	/	*NLOS*
8 kbps	3 km/h	-28,6 dB	/	-15,8 dB	-16,6 dB	/	-3,8 dB	7,2 dB	/	20 dB
	50 km/h	-28,5 dB	/	-24,3 dB	-16,5 dB	/	-12,3 dB	7,3 dB	/	11,5 dB
	120 km/h	-27,8 dB	/	-25,2 dB	-15,8 dB	/	-13,2 dB	8 dB	/	10,6 dB
	250 km/h	-27,4 dB	/	-6 dB	-15,4 dB	/	-	8,4 dB	/	-
64 kbps	3 km/h	-21,8 dB	/	-8 dB	-9,8 dB	/	-	5 dB	/	18,8 dB
	50 km/h	-21,8 dB	/	-16,7 dB	-9,8 dB	/	-4,7 dB	5 dB	/	10 dB
	120 km/h	-21,3 dB	/	-18 dB	-9,3 dB	/	-6 dB	5,5 dB	/	8,8 dB
	250 km/h	-21,1 dB	/	-10,1 dB	-9,1 dB	/	-	5,7 dB	/	16,7 dB
128 kbps	3 km/h	-19,5 dB	/	-10,5 dB	-7,5 dB	/	-	4,3 dB	/	13,3 dB
	50 km/h	-19,4 dB	/	-17,8 dB	-7,4 dB	/	-5,8 dB	4,4 dB	/	6 dB
	120 km/h	-18,8 dB	/	-17,7 dB	-6,8 dB	/	-5,7 dB	4,9 dB	/	6,1 dB
	250 km/h	-18,9 dB	/	-15,5 dB	-6,9 dB	/	-3,5 dB	4,9 dB	/	8,2 dB
256 kbps	3 km/h	-16,4 dB	/	-1,6 dB	-4,4 dB	/	-	4,3 dB	/	19,2 dB
	50 km/h	-16,6 dB	/	-9,4 dB	-4,6 dB	/	-	4,2 dB	/	11,4 dB
	120 km/h	-16,1 dB	/	-11,4 dB	-4,1 dB	/	-	4,6 dB	/	9,4 dB
	250 km/h	-16,1 dB	/	-12 dB	-4,1 dB	/	0 dB	4,7 dB	/	8,8 dB
384 kbps	3 km/h	-14 dB	/	-	-2 dB	/	-	5 dB	/	20,2 dB
	50 km/h	-14,1 dB	/	-6,5 dB	-2,1 dB	/	-	4,9 dB	/	12,5 dB
	120 km/h	-13,6 dB	/	-7,5 dB	-1,6 dB	/	-	5,4 dB	/	11,4 dB
	250 km/h	-13,6 dB	/	-2,3 dB	-1,6 dB	/	-	5,4 dB	/	16,1 dB

6.2.2.3 Demodulation in ITU Channel model B conditions

The average $\frac{S-CCPCH\_E_c}{I_{or}}$ power ratio is specified for 2 UE locations: 20 % around spot centre and spot borders.

Empty compartments mean the service is not reachable (situations suffering from too high inter-spot interference).

Table 6.15: FACH parameters in ITU channel model B conditions

Parameter	Unit	Test 1	Test 2
Phase reference		P-CPICH	
$\hat{I}_{or}/I_{oc}$	dB	9	-3
I_{oc}	dBm/3,84 MHz	-60	
Information Data Rate	kbps	20 % spot centre	Spot border

Table 6.16: FACH requirements in ITU channel model B conditions

Data rate	Speed	$\frac{S-CCPCH\_E_c}{I_{or}}$		$\frac{E_b}{N_t}$
		$\frac{\hat{I}_{or}}{I_{oc}} = 9dB$	$\frac{\hat{I}_{or}}{I_{oc}} = -3dB$	
		LOS / *NLOS*	LOS / *NLOS*	LOS / *NLOS*
8 kbps	3 km/h	-28,1 dB / -17,2 dB	-16,1 dB / -5,3 dB	7,7 dB / 10,1 dB
	50 km/h	-28 dB / -24,6 dB	-16 dB / -12,7 dB	7,8 dB / 11,2 dB
	120 km/h	-27,2 dB / -25,3 dB	-15,2 dB / -13,3 dB	8,7 dB / 10,5 dB
	250 km/h	-26,8 dB / -12,4 dB	-14,8 dB / -0,5 dB	9 dB / 23,3 dB
64 kbps	3 km/h	-21,3 dB / -9,3 dB	-9,3 dB / -	5,5 dB / 8,8 dB
	50 km/h	-21,4 dB / -17,1 dB	-9,4 dB / -5,2 dB	5,4 dB / 9,6 dB
	120 km/h	-20,9 dB / -18,2 dB	-8,9 dB / -6,2 dB	5,9 dB / 8,6 dB
	250 km/h	-20,6 dB / -12,1 dB	-8,6 dB / -0,1 dB	6,1 dB / 14,6 dB
128 kbps	3 km/h	-19,2 dB / -11,3 dB	-7,2 dB / -	4,6 dB / 6,8 dB
	50 km/h	-19 dB / -17,8 dB	-7 dB / -5,9 dB	4,8 dB / 5,9 dB
	120 km/h	-18,5 dB / -17,7 dB	-6,5 dB / -5,8 dB	5,3 dB / 6 dB
	250 km/h	-18,4 dB / -15,6 dB	-6,4 dB / -3,6 dB	5,4 dB / 8,1 dB
256 kbps	3 km/h	-15,8 dB / -3,1 dB	-3,8 dB / -	5 dB / -
	50 km/h	-16,1 dB / -9,8 dB	-4,1 dB / -	4,7 dB / 10,9 dB
	120 km/h	-15,7 dB / -11,6 dB	-3,7 dB / -	5,1 dB / 9,1 dB
	250 km/h	-15,7 dB / -12,1 dB	-3,7 dB / -0,1 dB	5,1 dB / 8,6 dB
384 kbps	3 km/h	-13,3 dB / -0,4 dB	-1,3 dB / -	5,7 dB / 9,3 dB
	50 km/h	-13,6 dB / -7,1 dB	-1,6 dB / -	5,4 dB / 11,8 dB
	120 km/h	-13,2 dB / -8,1 dB	-1,2 dB / -	5,8 dB / 10,8 dB
	250 km/h	-13,1 dB / -3,4 dB	-1,1 dB / -	5,9 dB / 15,5 dB

6.2.2.4 Demodulation in ITU Channel model C conditions

The average $\frac{S-CCPCH\_E_c}{I_{or}}$ power ratio is specified for 2 UE locations: 20 % around spot centre and spot borders.

Empty compartments mean the service is not reachable (situations suffering from too high inter-spot interference).

Table 6.17: FACH parameters in ITU channel model C conditions

Parameter	Unit	Test 1	Test 2
Phase reference		P-CPICH	
$\hat{I}_{or}/I_{oc}$	dB	9	-3
I_{oc}	dBm/3,84 MHz	-60	
Information Data Rate	kbps	20 % spot centre	Spot border

Table 6.18: FACH requirements in ITU channel model C conditions

Data rate	Speed	$\frac{S-CCPCH\_E_c}{I_{or}}$, $\frac{\hat{I}_{or}}{I_{oc}} = 9dB$ LOS / NLOS		$\frac{S-CCPCH\_E_c}{I_{or}}$, $\frac{\hat{I}_{or}}{I_{oc}} = -3dB$ LOS / NLOS		$\frac{E_b}{N_t}$ LOS / NLOS	
		LOS	NLOS	LOS	NLOS	LOS	NLOS
8 kbps	3 km/h	-26,8 dB	-18 dB	-14,8 dB	-7,6 dB	9 dB	
	50 km/h	-26,7 dB	-24 dB	-14,7 dB	-13,6 dB	9,1 dB	10 dB
	120 km/h	-25,4 dB	-24,3 dB	-13,4 dB	-13,8 dB	10,4 dB	9,8 dB
	250 km/h	-25 dB	-19,7 dB	-13 dB	-9,3 dB	10,8 dB	14,4 dB
64 kbps	3 km/h	-19,9 dB	-10,1 dB	-8 dB	-	6,8 dB	0 dB
	50 km/h	-20 dB	-16,5 dB	-8 dB	-6,1 dB	6,7 dB	8,5 dB
	120 km/h	-19,6 dB	-17,2 dB	-7,6 dB	-6,8 dB	7,2 dB	7,8 dB
	250 km/h	-19,2 dB	-13,6 dB	-7,2 dB	-3,2 dB	7,6 dB	11,4 dB
128 kbps	3 km/h	-18,2 dB	-11,3 dB	-6,3 dB	-0,9 dB	5,5 dB	
	50 km/h	-17,9 dB	-16,4 dB	-6 dB	-6 dB	5,8 dB	5,6 dB
	120 km/h	-17,3 dB	-16,2 dB	-5,3 dB	-5,8 dB	6,4 dB	5,7 dB
	250 km/h	-17,3 dB	-14,7 dB	-5,3 dB	-4,3 dB	6,5 dB	7,3 dB
256 kbps	3 km/h	-14,1 dB	-4,7 dB	-2,2 dB	-	6,6 dB	
	50 km/h	-14,6 dB		-2,6 dB		6,1 dB	
	120 km/h	-14,3 dB		-2,4 dB		6,4 dB	
	250 km/h	-14,3 dB		-2,3 dB		6,4 dB	
384 kbps	3 km/h	-11 dB	-1,6 dB	-	-	8 dB	0 dB
	50 km/h	-11,6 dB	-7,1 dB	-	-	7,4 dB	10,1 dB
	120 km/h	-11,3 dB	-7,9 dB	-	-	7,7 dB	9,4 dB
	250 km/h	-11 dB	-2,7 dB	-	-	7,9 dB	13,6 dB

6.2.2.5 Demodulation in IMR environment conditions

FACH parameters for other cell interference are specified as reference [11].

Table 6.19: FACH requirements in IMR conditions

Case 1			**Case 2**			**Case 3**		
Data rate	$\frac{S-CCPCH\_E_c}{I_{or}}$	$\frac{E_b}{N_t}$	**Data rate**	$\frac{S-CCPCH\_E_c}{I_{or}}$	$\frac{E_b}{N_t}$	**Data rate**	$\frac{S-CCPCH\_E_c}{I_{or}}$	$\frac{E_b}{N_t}$
8 kbps	-18,5 dB	17 dB	8 kbps	-9,4 dB	13,1 dB	8 kbps	-11,7 dB	11,3 dB
64 kbps	-10,3 dB	16,1 dB	64 kbps	-1,8 dB	11,7 dB	64 kbps	-7 dB	7,1 dB
128 kbps	-11,9 dB	11,5 dB	128 kbps	-1,9 dB	8,6 dB	128 kbps	-5,5 dB	5,6 dB
256 kbps			256 kbps			256 kbps		
384 kbps	-1,9 dB	16,7 dB	384 kbps	-	-	384 kbps	-3,7 dB	8,7 dB
Case 4			**Case 5**			**Case 6**		
Data rate	$\frac{S-CCPCH\_E_c}{I_{or}}$	$\frac{E_b}{N_t}$	**Data rate**	$\frac{S-CCPCH\_E_c}{I_{or}}$	$\frac{E_b}{N_t}$	**Data rate**	$\frac{S-CCPCH\_E_c}{I_{or}}$	$\frac{E_b}{N_t}$
8 kbps	-13,5 dB	15,3 dB	8 kbps	-24,3 dB	11,2 dB	8 kbps	-9,6 dB	13,5 dB
64 kbps	-5,6 dB	14,2 dB	64 kbps	-21,9 dB	4,5 dB	64 kbps	-5,2 dB	8,9 dB
128 kbps	-6,7 dB	10,1 dB	128 kbps	-17,7 dB	5,7 dB	128 kbps	-4,1 dB	6,9 dB
256 kbps			256 kbps			256 kbps		
384 kbps	-	-	384 kbps	-4,7 dB	11,1 dB	384 kbps	-1,4 dB	11 dB

6.2.2.6 Demodulation in combined satellite and transparent IMR environment conditions

Table 6.20: FACH parameters in combined satellite and transparent IMR environment conditions

Parameter	Unit				
Phase reference		P-CPICH			
$\hat{I}_{or}/I_{oc}$	dB	-3	-3	3	6
I_{oc}	dBm/3,84 MHz	-60			
Information Data Rate	kbps	8	64	128	384

Table 6.21: FACH requirements in combined satellite and transparent IMR conditions

Data rate	Speed	$\frac{S-CCPCH\_E_c}{I_{or}}$ High power / Low power	$\frac{E_b}{N_t}$ High power / Low power
8 kbps	3 km/h	-12,2 dB / -11,7 dB	10,1 dB / 10,8 dB
	50 km/h	-13,9 dB / -13,6 dB	8,5 dB / 8,8 dB
	120 km/h	-13,2 dB / -12,9 dB	9,2 dB / 9,5 dB
	250 km/h	-11,6 dB / -11,1 dB	10,8 dB / 11,3 dB
64 kbps	3 km/h	-4,5 dB / -3,9 dB	8,8 dB / 9,5 dB
	50 km/h	-6,7 dB / -6,3 dB	6,7 dB / 7,1 dB
	120 km/h	-6,2 dB / -6 dB	7,1 dB / 7,4 dB
	250 km/h	-4,8 dB / -4,5 dB	8,6 dB / 8,9 dB
128 kbps			
	50 km/h	-4,9 dB / -4,5 dB	5,4 dB / 5,9 dB
	120 km/h	-4,2 dB / -3,9 dB	6,1 dB / 6,5 dB
	250 km/h	-3 dB / -2,7 dB	7,3 dB / 7,7 dB
384 kbps	3 km/h	-0,6 dB / -0,1 dB	9,3 dB / 10,1 dB
	50 km/h	-2,4 dB / -1,9 dB	7,4 dB / 8,1 dB
	120 km/h	-2,2 dB / -1,8 dB	7,7 dB / 8,3 dB
	250 km/h	-0,8 dB / -0,2 dB	9,1 dB / 9,8 dB

Performance requirements for the candidate test cases from Satin are presented hereafter (applicable to low power IMRs).

FACH parameters for other cell interference are specified as [11].

Table 6.22: FACH requirements in combined satellite and low power IMR conditions; satin test cases

S-Case 1			**S-Case 2**			**S-Case 3**		
Data rate	$\frac{S-CCPCH\_E_c}{I_{or}}$	$\frac{E_b}{N_t}$	**Data rate**	$\frac{S-CCPCH\_E_c}{I_{or}}$	$\frac{E_b}{N_t}$	**Data rate**	$\frac{S-CCPCH\_E_c}{I_{or}}$	$\frac{E_b}{N_t}$
8 kbps	-18,5 dB	17 dB	8 kbps	-9,6 dB	12,9 dB	8 kbps	-14 dB	9,1 dB
64 kbps	-10,3 dB	16,1 dB	64 kbps	-1,8 dB	11,7 dB	64 kbps	-7 dB	7,1 dB
128 kbps	-11,9 dB	11,5 dB	128 kbps	-1,9 dB	8,6 dB	128 kbps	-5,4 dB	5,6 dB
384 kbps	-1,9 dB	16,7 dB	384 kbps	-	-	384 kbps	-3,7 dB	8,7 dB
S-Case 4			**S-Case 5**			**S-Case 6**		
Data rate	$\frac{S-CCPCH\_E_c}{I_{or}}$	$\frac{E_b}{N_t}$	**Data rate**	$\frac{S-CCPCH\_E_c}{I_{or}}$	$\frac{E_b}{N_t}$	**Data rate**	$\frac{S-CCPCH\_E_c}{I_{or}}$	$\frac{E_b}{N_t}$
8 kbps	-19,2 dB	11,2 dB	8 kbps	-18,7 dB	8,6 dB	8 kbps	-10,9 dB	11,4 dB
64 kbps	-12,5 dB	8,9 dB	64 kbps	-11,9 dB	6,4 dB	64 kbps	-4,7 dB	8,7 dB
128 kbps	-11,4 dB	6,9 dB	128 kbps	-	-	128 kbps	-2,9 dB	7,4 dB
384 kbps	-1,4 dB	11 dB	384 kbps	-1,7 dB	8,2 dB	384 kbps	-	-

6.2.2.7 Demodulation in combined satellite and regenerative IMR environment conditions

The present clause presents demodulation performance in case of regenerative IMR i.e. soft combining from 2 cells is applied. The number of rake receiver fingers is limited to 6, the path loss cell difference between combined signals is set to 4 dB.

Table 6.23: Demodulation performance; Soft combining; 2 cells

Data rate	UE speed	Propagation model	Eb/Nt	S-CCPCH_Ec/Ior
64 kbps	3 km/h	Pedestrian A	12,5 dB	-2,5 dB
		Vehicular A	10,4 dB	-3,6 dB
	50 km/h	Pedestrian A	7,3 dB	-7,7 dB
		Vehicular A	6,7 dB	-7,2 dB
128 kbps	3 km/h	Pedestrian A	12,5 dB	0,5 dB
		Vehicular A	10,4 dB	-0,6 dB
	50 km/h	Pedestrian A	7,2 dB	-4,8 dB
		Vehicular A	6,6 dB	-4,3 dB

6.2.2.8 Demodulation in aeronautical environment

The requirements hereafter are applicable to a velocity of 800 km/h.

The average $\frac{S-CCPCH\_E_c}{I_{or}}$ power ratio is specified for 2 UE locations: 20 % around spot centre and spot borders.

Table 6.24: FACH parameters in ITU channel model C conditions

Parameter	Unit	Test 1	Test 2
Phase reference		P-CPICH	
$\hat{I}_{or}/I_{oc}$	dB	9	-3
I_{oc}	dBm/3,84 MHz	-60	
Information Data Rate	kbps	20 % spot centre	Spot border

Table 6.25: FACH requirements in aeronautical environment

Data rate	$\frac{S-CCPCH\_E_c}{I_{or}}$		$\frac{E_b}{N_t}$
	$\frac{\hat{I}_{or}}{I_{oc}}=9dB$	$\frac{\hat{I}_{or}}{I_{oc}}=-3dB$	
8 kbps	-26,3 dB	-14,3 dB	9,5 dB
64 kbps	-20 dB	-8 dB	6,7 dB
128 kbps	-17,9 dB	-5,9 dB	5,9 dB
256 kbps	-15 dB	-3 dB	5,7 dB
384 kpbs	-12,8 dB	-0,8 dB	6,2 dB

6.2.3 Demodulation requirements synthesis

6.2.3.1 Fast fading propagation link margin

6.2.3.1.1 Satellite signal LOS view

In case UE is in ITU satellite models with LOS view of the satellite signal, simulation results show required propagation link margin is homogeneous all the test services.

Table 6.26: Maximum Propagation Link Margin; LOS ITU models

Service type	Downlink
ITU Model A (rural)	2,1 dB
ITU Model B (sub-urban)	2,8 dB
ITU Model C (urban)	4,5 dB

6.2.3.1.2 Satellite signal NLOS view

When UEs are not in LOS view of the satellite signal, the required link margin becomes more critical, particularly for UEs at low speed (3 km/h), and is test service data rate dependent. Link margins are defined for two types of system deployment: satellite only (NLOS) and combined satellite/transparent IMRs.

Table 6.27: Maximum Propagation Link Margin; NLOS ITU models and combined Satellite + transparent IMR

Service type	Downlink	
	Link margin Sat. only	Link margin Sat. + IMR
Audio 8 kbps	17 dB	4,5 dB
Data 64 kbps	14,7 dB	5,5 dB
Data 128 kbps	9,8 dB	4,5 dB
Data 256 kbps	7,2 dB	
Data 384 kbps	10,2 dB	6,4 dB

IMR deployment allows to reduce link margin. This advantage is to be added to the fact IMRs deployment solves the problem of path blockage inherent to satellite systems without satellite diversity.

Note that these link margins are defined with the assumption that IMRs do not implement antenna diversity. If IMRs antenna diversity is implemented, the required link margin is substantially reduced.

Note also that introducing this propagation link margin for NLOS satellite view drives to the situation that the system is designed for accepting short range indoor penetration, as specified by ITU recommendation for Indoor Satellite Environment (10 dB to 15 dB margin [2]).

6.2.3.1.3 Shadowing margin

Shadowing margin (trees, etc.) varies according to coverage area elevation. Shadowing margins in Europe, at 2,2 GHz, are given in the table 6.28:

Table 6.28: Shadowing margin versus elevation

UE Elevation	Margin (dB)
10°	30,1dB
15°	19,8 dB
20°	14,7 dB
25°	11,7 dB
30°	9,6 dB
35°	8,2 dB
40°	7,1 dB
50°	5,5 dB

6.2.3.2 Increasing interleaving depth

Required E_b/N_t, and thus average $\frac{S-CCPCH\_E_c}{I_{or}}$ power ratio, can be decreased by increasing interleaving depth.

One drawback of increasing interleaving depth is that this requires increasing UE memory size for buffering frames. This could be sensible for high data rate services (256 or 384 kbps).

Simulations have been run with interleaving depth of 4 and 8 for all the test environments. The simulation results show a decrease of the required propagation link margin, and an homogenisation whatever the service type.

The maximum required link margin and the reduction of the required link margin to be compared to the test cases are depicted in table 6.29.

Table 6.29: Link margin gain with interleaving depth 4 and 8

Service type	TTI = 40ms		TTI = 80ms	
	Link margin	Margin gain	Link margin	Margin gain
Audio 8 kbps	10,7 dB	5,3 dB	8,9 dB	7,1 dB
Data 64 kbps	11,9 dB	2,3 dB	10 dB	4,2 dB
Data 128 kbps	12 dB	7,4 dB	10 dB	9,4 dB
Data 256 kbps	12,2 dB	3,8 dB	10,4 dB	2,1 dB

6.2.3.3 Spatial diversity

Reception quality can be improved with two kinds of spatial diversity: UE antenna diversity and satellite diversity.

NOTE: Satellite antenna diversity is not considered for satellite complexity reasons.

6.2.3.3.1 UE antenna diversity

UE may be equipped with two reception antennas.

Simulation results show a reduction of the required link margin regarding the propagation channel as depicted in table 6.30.

Table 6.30: Link margin reduction; UE antenna diversity

Propagation channel	Link margin reduction
AWGN	3
Case 1, S-case 1	6,5
Case 2, S-case 2	5,8
Case 3, S-case 3	3,6
Case 4	7
Case 5, S-case 5	4
Case 6, S-case 6	4
S-case 4	4,4
ITU A, B, C (LOS)	3 dB to 3,8 dB
ITU A, B (NLOS)	4 dB to 8 dB
ITU C NLOS	3 dB to 6 dB
High and low power IMR	3 dB to 3,6 dB

6.2.3.3.2 Satellite diversity

Satellite diversity can be provided when the system is built with several satellites. This is an alternative to IMRs deployment for solving:

- path blockage problem inherent to satellite systems;
- propagation margin reduction.

UEs receive simultaneously the same service from several satellites. Satellite diversity takes benefits of the UE Rake receiver capability for MBMS soft combining.

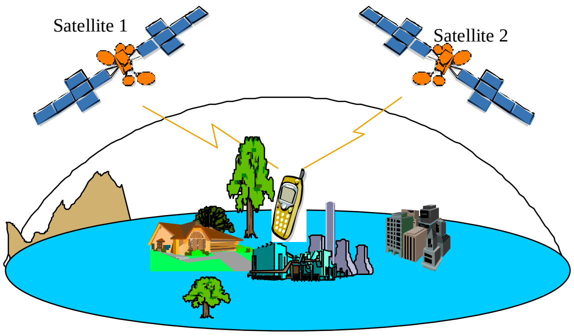


Figure 6.1: Satellite diversity

Simulations were driven for several values of the path loss difference between satellite 1 and satellite 2, in ITU channel model A (NLOS) environment for a UE velocity of 3 km/h.

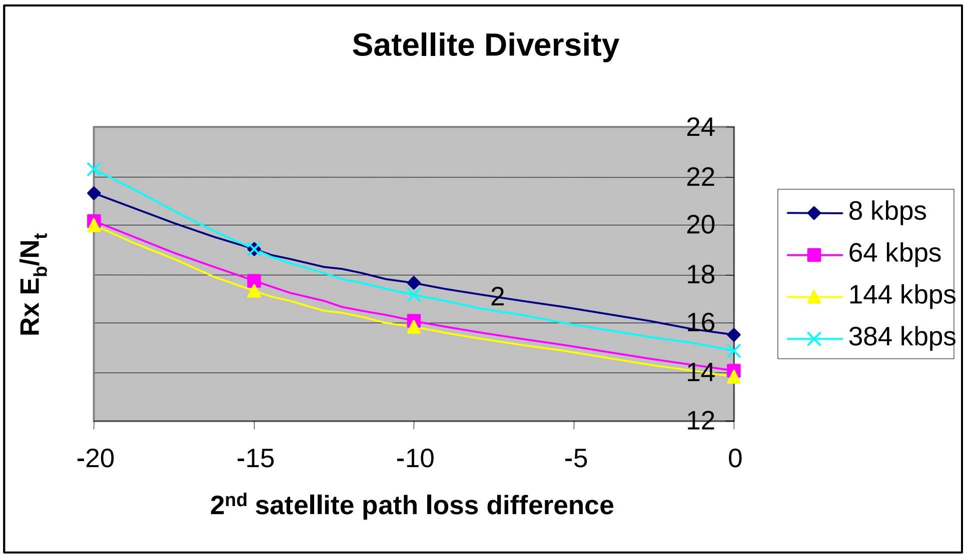


Figure 6.2: Satellite diversity; E_b/N_t as a function of satellites path loss difference, ITU channel model A, 3 km/h

Typical path loss difference between satellites is foreseen to be -10 dB in sub-urban environment and -20 dB in urban environment.

The case when satellites path loss difference is -20 dB is a path blockage situation, i.e. UE has a view on only one satellite.

6.2.4 Acquisition efficiency

Performance of initial spot synchronization was evaluated for several radio environments (see [35] and [36]). They are resumed hereafter.

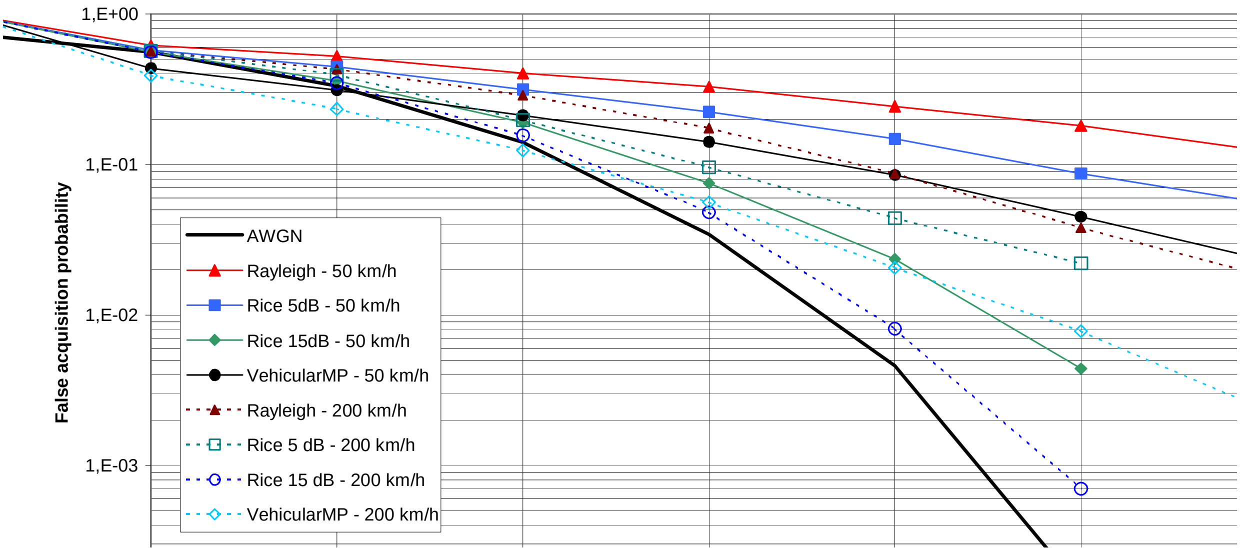


Figure 6.3: False acquisition probability vs. Ec/No, step 1

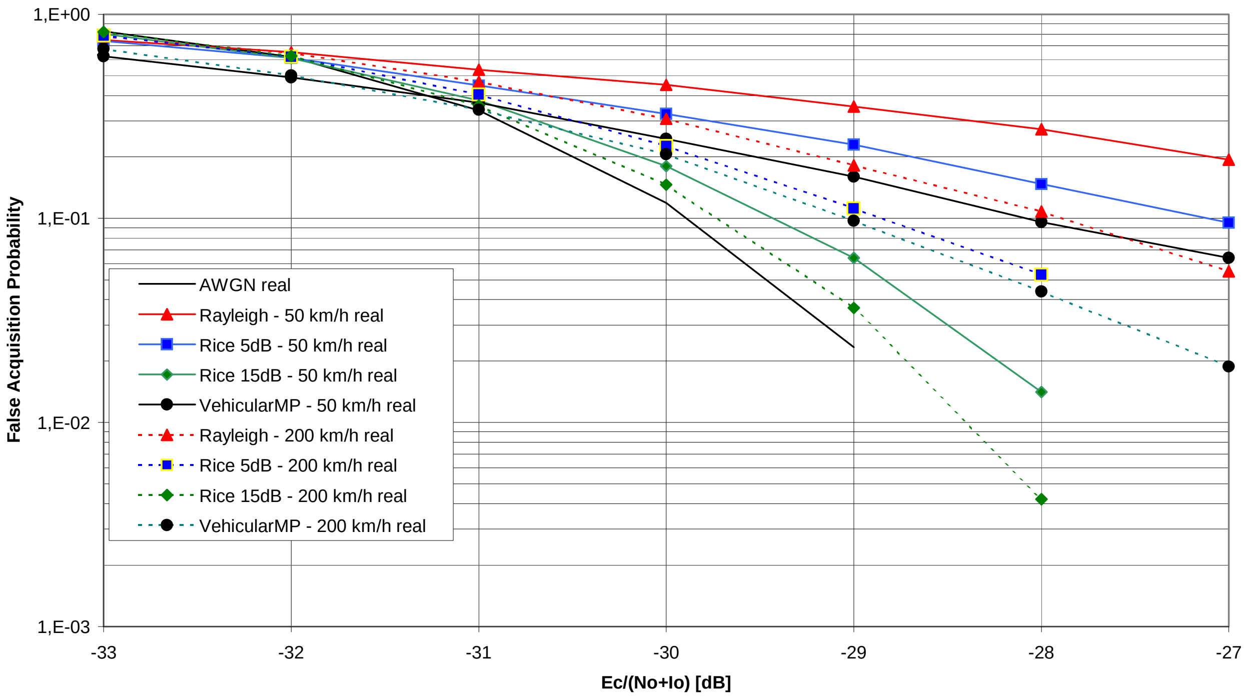


Figure 6.4: False acquisition probability vs. Ec/No, step 2

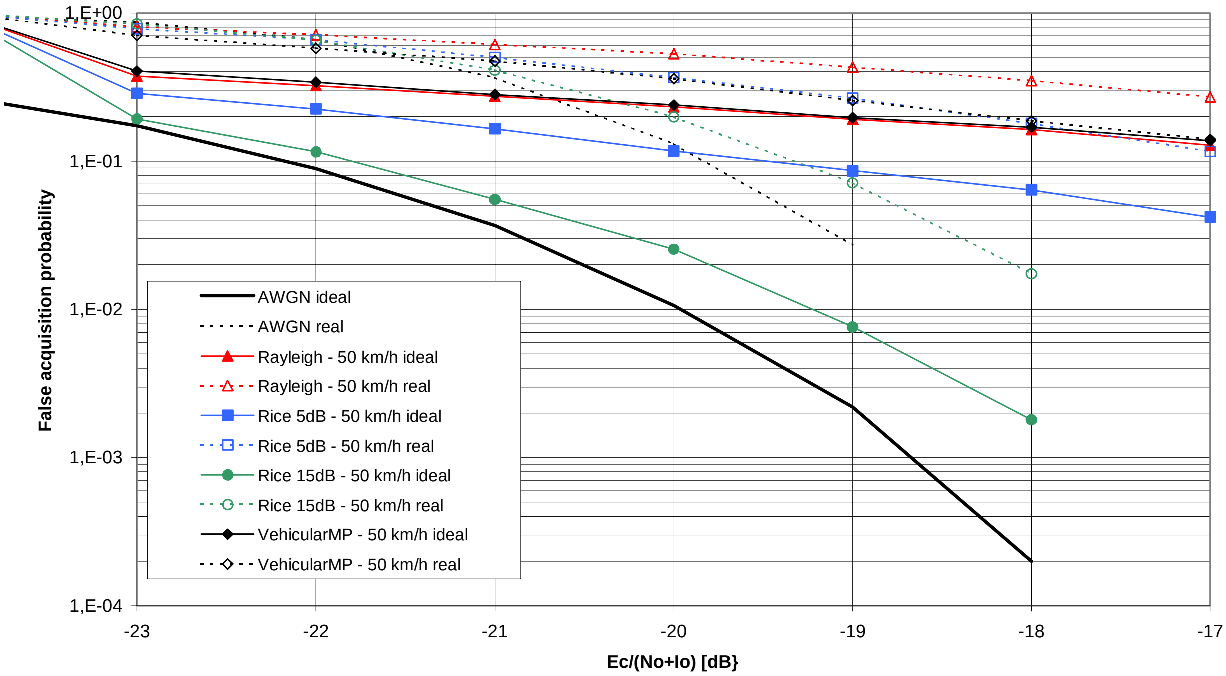


Figure 6.5: False acquisition probability vs. Ec/No, step 3, 50 km/h

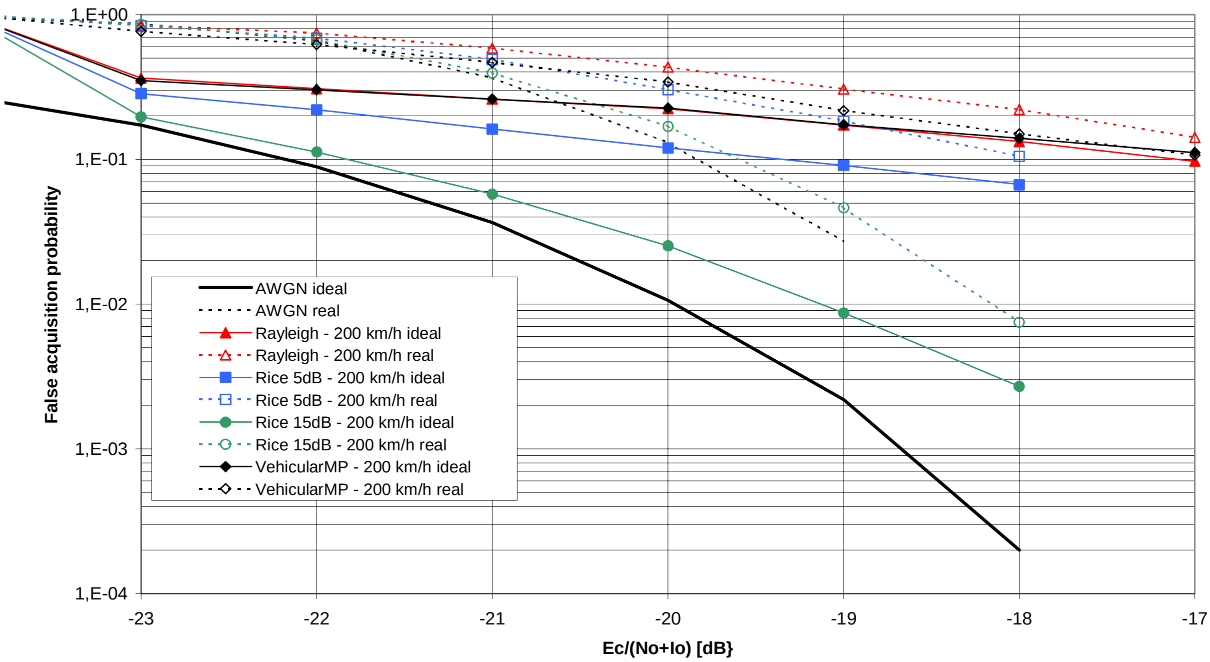


Figure 6.6: False acquisition probability vs. Ec/No, step 3, 200 km/h

6.3 Satellite transmitter characteristics

Satellite transmission in the downlink MSS band is constrained by necessity to limit interference to terrestrial UMTS.

It is assumed that the main constraint will be due to the protection of the reception by IMT-2000 UEs, in the lower adjacent terrestrial channel.

For a 74 dBW satellite EIRP, the required attenuation level in the core band compared to co-channel operation can be derived as follows:

Table 6.31: Satellite transmitter characteristics

UE receiver	Max Antenna gain	0	dB
	Feeder loss	0	dB
	Tilt angle	0,0	°down
	Rx Noise Figure	-4,5	dB
	Rx Noise level	-129,5	dBW/MHz
	Required I/N	-10	dB
	Maximum tolerable ACI	-129,5	dBW/MHz
Satellite	Satellite altitude	36 000	Km
	Frequency	2 170	MHz
	Path loss	191,6	dB
	Maximum tolerable satellite EIRP density	46,62	dBW/MHz
	Satellite EIRP	74	dBW
	Bandwidth	3,84	MHz
	Max in-band EIRP density	68,16	dBW/MHz
	Required attenuation	21,54	dB

The satellite spectrum mask and Adjacent Channel Leakage Ratio (ACLR) are as follows:

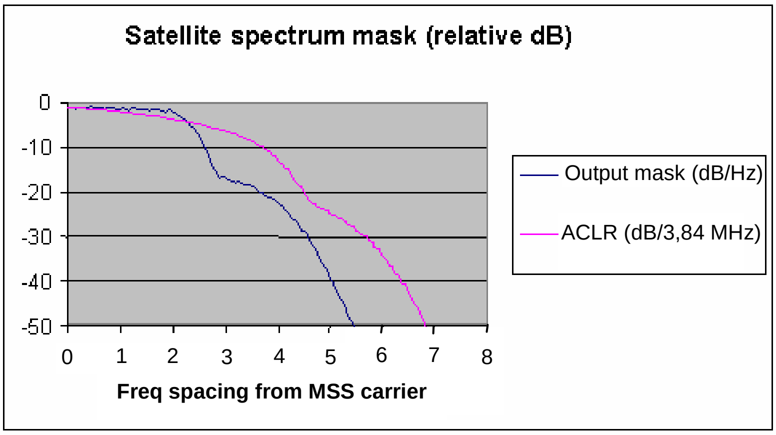


Figure 6.7: Satellite spectrum emission mask and ACLR

6.4 UE receiver characteristics

If terrestrial 3GPP UE are to be operated then their radio implementation must be upgraded for frequency agility to MSS bands. The UE RF performances are:

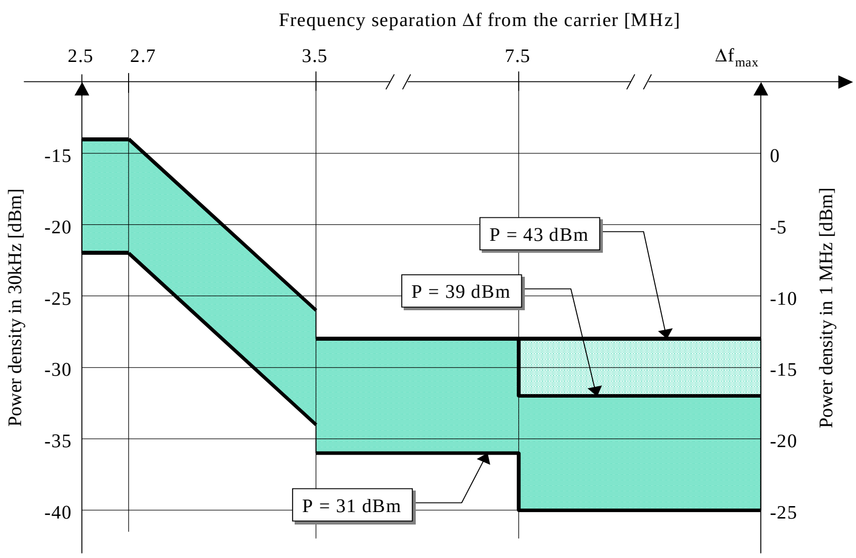
Table 6.32: UE RF performance

Receive frequency (MHz)	**2 170 to 2 200 MHz**		
UE type	Handset	Handheld	Others
Receive polarization	Linear	Circular	Circular
Noise figure	4,5 dB	4,5 dB	2 dB
Receiver noise floor	-103,5 dBm	103,5 dBm	106 dBm
Antenna gain	0	1 dBi	4/14 dBi
ACS (Adjacent Channel Selectivity) as a function of carrier separation (from TS 25 101)	5 MHz	10 MHz	
	33 dB	33 dB	

6.5 IMR transmitter characteristics

Table 6.33: IMR power characteristics

Coverage area (°)	**Up to 360° (i.e. 120° per sector)**		
IMR classes	Wide area repeaters for macro-cell application	Medium range repeaters for micro-cell	Local area repeaters for pico-cell
Assumed height of IMRs (m)	30	6	6
Maximum output power (dBm)	43	30	24
Maximum Antenna gain (Tx) (dBi)	15	6	0
Transmission mask	Compliant with the 3GPP requirements for Node B in TS 125 104 [12].		
ACLR (Adjacent Channel Leakage Ratio) as a function of carrier separation - from TS 125 104 [12].	5 MHz	10 MHz	15 MHz
	45 dB	50 dB	67 dB



Illustrative diagram of spectrum emission mask

Figure 6.8: IMR transmission mask

7 System performances

7.1 Link budgets

Link budgets are evaluated with the following assumptions:

- GEO constellation (satellite altitude ~ 36 000 km thus free space loss close to 192 dB);
- an average UE elevation of 30°, in rural areas;
- UE located at spot border/End Of Coverage (EOC). This means the worst case to be compared to centre spot where higher capacity can be provided, particularly for the case when the same frequency carrier is allocated to all the spots;
- Satellite EIRP set to 71 dBW at EOC, 75 dBW at center spot.

Required link margin for shadowing varies with UE elevation. Link budgets are calculated for UE elevation of 30°, i.e. a required link margin of 9,6 dB, and assuming every spot is.

Note that the link margin for shadowing of 9,6 dB covers the link margin which would be required for sub-urban and urban environments.

For other spots interference calculation, it is assumed every spot is equally traffic loaded (uniform traffic distribution) and is allocated the same transmit power. This assumption is realistic in the sense that a real spots power allocation could be based on distributing transmit power among spots based on coverage area elevation, i.e. on the required shadowing margin. It is assumed the Eb/Nt feeder link degradation is kept less than 0,2 dB (see [48]).

Link budgets are calculated for a Block Error Ratio (BLER) less than 10-2 in AWGN channel conditions, i.e. static conditions. UE implementation margin is included in Eb/Nt (see clause 6.2.2). Degradation due to UE mobility is covered by the link budget margin.

In case of audio 8 kbps service, a traffic activity factor of 0,5 is assumed.

No satellite diversity is applied, there is only one satellite in view.

The levels of power flux density (pfd) are kept below thresholds set by ITU frequency sharing recommendations (see [31]), i.e.:

- UE elevation > 25° → pfd ≤ -118 dBW/m2 MHz;
- UE elevation < 25° → pfd ≤ -122,5 dBW/m2 MHz.

The downlink capacity is limited by:

- on board power;
- the maximum number of downlink channelization (due to the codes tree allocation scheme) and scrambling codes (1 primary scrambling code + maximum 15 secondary scrambling codes) (see [49]);
- the downlink interference on both primary and secondary scrambling code.

In case secondary downlink scrambling codes are used, sets of channelization codes under different scrambling codes are not orthogonal against each other. This is taken into account for interference caused to channelization codes mapped to primary scrambling code. Also is checked interference cause to channelization codes mapped to secondary scrambling code.

Power level received at UE antenna connector is given for indication. It is to be compared with the Rx sensitivity level given in 3GPP TS 25 101 [11]. 3GPP specifies a minimum value of -117 dBm for 12,2 kbps, handset configuration.

7.1.1 Audio service 8 kbps

Table 7.1: Link budget; Audio 8 kbps

FORWARD LINK BUDGET		Handset	Handheld	Vehicular	Transportable	Handset	Handheld	Vehicular
Satellite Location	°E	10				10		
Orbital Height	Km	35786				35786		
Unique Scrambling code		no	no	no	no	no	no	no
Center spot		no	no	no	no	YES	YES	YES
Calculation of interference from spot n+2		yes	yes	yes	yes	yes	yes	yes
ACLR at 5 MHz (Spot n+1)	dB	21,0	21,0	21,0	21,0	21,0	21,0	21,0
Antenna C/I (at EOC) Spot n+2	dB	12,0	12,0	12,0	12,0	15,0	15,0	15,0
Max EIRP per spot (EOC)	dBW	71,0	71,0	71,0	71,0	75,0	75,0	75,0
Chip Rate	Mchip/s	3,840						
Chip SRC Roll-off Factor	-	0,22						
Full FDM Bandwidth	MHz	4,68	4,68	4,68	4,68	4,68	4,68	4,68
Data Rate	**bit/s**	8 000	8 000	8 000	8 000	8 000	8 000	8 000
Traffic Activity Factor	**-**	0,5	0,5	0,5	0,5	0,5	0,5	0,5
Required Eb/(No+Io)	**dB**	6,30	6,30	6,30	6,30	6,30	6,30	6,30
UE elevation	°	30	30	30	30	30	30	30
Slant Range	Km	38611,2	38611,2	38611,2	38611,2	38611,2	38611,2	38611,2
Downlink Frequency	MHz	2200						
Availability (/year)	%	99,96						
Polarization (C/V/H)	C/V/H	Circular						
OBO and EIRP per code Calculation								
Total OBO	dB	-2						
Total OBOu	dB	-2,9	-2,9	-2,9	-2,9	-2,9	-2,9	-2,9
Signaling OBO	dB	-9,85	-9,85	-9,85	-9,85	-9,85	-9,85	-9,85
Common Physical Channels	dBW	61,15	61,15	61,15	61,15	65,15	65,15	65,15
Carrier Total EIRP for traffic per spot	dBW	67,18	67,18	67,18	67,18	71,18	71,18	71,18
On Board EIRP per SCCPCH (per traffic	dBW	47,74	44,51	42,97	42,85	47,80	46,84	46,65
Common Physical Channels Equivalent Traffic Codes	-	21,93	46,11	65,80	67,55	54,34	67,80	70,79
Losses (free space,rain, atmos.)	dB	191,11	191,11	191,11	191,11	191,11	191,11	191,11
UE Antenna Gain including polarisation losses	dBi	-3,0	1,0	4,0	14,0	-3,0	1,0	4,0
UE System Temp.	K	817,3	727,3	319,6	319,6	817,3	727,3	319,6
UE G/T	dB/K	-32,1	-27,6	-21,0	-11,0	-32,1	-27,6	-21,0
Thermal Noise Density, No	dBW/Hz	-199,5	-200,0	-203,6	-203,6	-199,5	-200,0	-203,6
Interference from adjacent spots	dBW	-149,2	-145,2	-142,2	-132,2	-1000,0	-1000,0	-1000,0
Interference from spot n+2 (Spain/Germany,	dBW	-140,2	-136,2	-133,2	-123,2	-139,2	-135,2	-132,2
Interference from 2ndary scrambling code	dBW	-1000,0	-1000,0	-137,2	-125,0	-1000,0	-133,7	-128,7
Total interference per channel	dBW	-139,7	-135,7	-131,3	-120,7	-139,2	-131,4	-127,1
-10*LOG(Spreading Bandwidth)	dB/Hz	-65,8	-65,8	-65,8	-65,8	-65,8	-65,8	-65,8
Interference Density, Io	dBW/Hz	-205,5	-201,5	-197,2	-186,5	-205,0	-197,2	-192,9
10*log(No+Io)	dBW/Hz	-198,5	-197,7	-196,3	-186,4	-198,4	-195,4	-192,6
Rx Power Flux Density	dBW/m²	-115,0	-118,2	-119,8	-119,9	-114,9	-115,9	-116,1
Total Received PFD	dBW/m²/1 MHz	-100,4	-100,4	-100,4	-100,4	-96,4	-96,4	-96,4
DL C/No	dBHz	56,1	57,4	62,4	72,3	56,2	59,7	66,1
DL C/Io	dBHz	62,1	58,9	56,1	55,3	61,7	57,0	55,5
DL C/(No+Io)	dBHz	55,1	55,1	55,2	55,2	55,1	55,1	55,1
DL Eb/(No+Io)	**dB**	16,1	16,1	16,1	16,1	16,1	16,1	16,1
Eb/No Losses due to Satellite Non-Linearities	dB	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Eb/No Losses due to feeder link degradation (I	dB	0,2	0,2	0,2	0,2	0,2	0,2	0,2
Overall Link Eb/(No+Io)	**dB**	15,9	15,9	15,9	15,9	15,9	15,9	15,9
Total C/(N+I)	**dB**	-11,8	-11,8	-11,8	-11,7	-11,8	-11,8	-11,8
SCCPCH Power level at UE antenna	dBW	-146,37	-145,60	-144,14	-134,26	-146,31	-143,27	-140,46
SCCPCH Power level at UE antenna	dBm	-116,37	-115,60	-114,14	-104,26	-116,31	-113,27	-110,46
Common channels power level at UE antenna	dBm	-102,96	-98,96	-95,96	-85,96	-98,96	-94,96	-91,96
Raw Margin	**dB**	9,6	9,6	9,6	9,6	9,6	9,6	9,6
Nb. Traffic Codes/Spot/Carrier	-	88,00	185,00	264,00	271,00	218,00	272,00	284,00
Capacity per spot per carrier	**Mbps**	0,352	0,74	1,056	1,084	0,872	1,088	1,136
Spectrum efficiency as ITU	bit/s/Hz	0,075	0,158	0,225	0,231	0,186	0,232	0,242
Power efficiency as ITU	-	2,56%	2,60%	2,56%	2,55%	2,58%	2,58%	2,58%

7.1.2 Data service 64 kbps

Table 7.2: Link budget; Data 64 kbps

FORWARD LINK BUDGET		Handset	Handheld	Vehicular	Transportable	Handset	Handheld	Vehicular
Satellite Location	°E	10				10		
Orbital Height	Km	35786				35786		
Unique Scrambling code		no	no	no	no	no	no	no
Center spot		no	no	no	no	YES	YES	YES
Calculation of interference from spot n+2		yes	yes	yes	yes	yes	yes	yes
ACLR at 5 MHz (Spot n+1)	dB	21,0	21,0	21,0	21,0	21,0	21,0	21,0
Antenna C/I (at EOC) Spot n+2	dB	12,0	12,0	12,0	12,0	15,0	15,0	15,0
Max EIRP per spot (EOC)	dBW	71,0	71,0	71,0	71,0	75,0	75,0	75,0
Chip Rate	Mchip/s	3,840						
Chip SRC Roll-off Factor	-	0,22						
Full FDM Bandwidth	MHz	4,68	4,68	4,68	4,68	4,68	4,68	4,68
Data Rate	**bit/s**	64 000	64 000	64 000	64 000	64 000	64 000	64 000
Traffic Activity Factor	**-**	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Required Eb/(No+Io)	**dB**	4,00	4,00	4,00	4,00	4,00	4,00	4,00
UE elevation	°	30	30	30	30	30	30	30
Slant Range	Km	38611,2	38611,2	38611,2	38611,2	38611,2	38611,2	38611,2
Downlink Frequency	MHz	2200						
Availability (/year)	%	99,96						
Polarization (C/V/H)	C/V/H	Circular						
OBO and EIRP per code Calculation								
Total OBO	dB	-2						
Total OBOu	dB	-2,9	-2,9	-2,9	-2,9	-2,9	-2,9	-2,9
Signaling OBO	dB	-9,85	-9,85	-9,85	-9,85	-9,85	-9,85	-9,85
Common Physical Channels	dBW	61,15	61,15	61,15	61,15	65,15	65,15	65,15
Carrier Total EIRP for traffic per spot	dBW	67,18	67,18	67,18	67,18	71,18	71,18	71,18
On Board EIRP per SCCPCH (per traffic	dBW	58,15	55,42	53,38	52,87	58,17	56,27	56,13
Common Physical Channels Equivalent Traffic Codes	-	1,99	3,74	5,98	6,73	4,99	7,73	7,98
Losses (free space,rain, atmos.)	dB	191,11	191,11	191,11	191,11	191,11	191,11	191,11
UE Antenna Gain including polarisation losses	dBi	-3,0	1,0	4,0	14,0	-3,0	1,0	4,0
UE System Temp.	K	817,3	727,3	319,6	319,6	817,3	727,3	319,6
UE G/T	dB/K	-32,1	-27,6	-21,0	-11,0	-32,1	-27,6	-21,0
Thermal Noise Density, No	dBW/Hz	-199,5	-200,0	-203,6	-203,6	-199,5	-200,0	-203,6
Interference from adjacent freq spots n+1	dBW	-147,0	-143,0	-140,0	-130,0	-1000,0	-1000,0	-1000,0
Interference from spot n+2	dBW	-138,0	-134,0	-131,0	-121,0	-137,0	-133,0	-130,0
Interference from 2ndary scrambling code	dBW	-1000,0	-1000,0	-1000,0	-1000,0	-1000,0	-1000,0	-131,0
Total interference per channel	dBW	-137,4	-133,4	-130,4	-120,4	-137,0	-133,0	-127,4
-10*LOG(Spreading Bandwidth)	dB/Hz	-65,8	-65,8	-65,8	-65,8	-65,8	-65,8	-65,8
Interference Density, Io	dBW/Hz	-203,3	-199,3	-196,3	-186,3	-202,8	-198,8	-193,3
10*log(No+Io)	dBW/Hz	-198,0	-196,6	-195,5	-186,2	-197,8	-196,3	-192,9
Rx Power Flux Density	dBW/m^2	-104,6	-107,3	-109,3	-109,9	-104,6	-106,5	-106,5
Total Received PFD	dBW/m^2/1 MHz	-100,4	-100,4	-100,4	-100,4	-96,4	-96,4	-96,4
DL C/No	dBHz	63,5	65,3	69,8	79,3	63,5	66,1	72,6
DL C/Io	dBHz	67,3	64,6	62,6	62,0	66,9	65,0	62,3
DL C/(No+Io)	dBHz	62,0	61,9	61,8	62,0	61,9	62,5	61,9
DL Eb/(No+Io)	**dB**	13,9	13,9	13,8	13,9	13,8	14,4	13,8
Eb/No Losses due to Satellite Non-Linearities	dB	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Eb/No Losses due to feeder link degradation (I	dB	0,2	0,2	0,2	0,2	0,2	0,2	0,2
Overall Link Eb/(No+Io)	**dB**	13,7	13,7	13,6	13,7	13,6	14,2	13,6
Total C/(N+I)	**dB**	-4,9	-5,0	-5,1	-4,9	-5,0	-4,4	-5,0
SCCPCH Power level at UE antenna	dBW	-135,96	-134,69	-133,73	-124,24	-135,94	-133,84	-130,98
SCCPCH Power level at UE antenna	dBm	-105,96	-104,69	-103,73	-94,24	-105,94	-103,84	-100,98
Common channels power level at UE antenna	dBm	-102,96	-98,96	-95,96	-85,96	-98,96	-94,96	-91,96
Raw Margin	**dB**	9,7	9,7	9,6	9,7	9,6	10,2	9,6
Nb. Traffic Codes/Spot/Carrier	-	8,00	15,00	24,00	27,00	20,00	31,00	32,00
Capacity per spot per carrier	**Mbps**	0,512	0,96	1,536	1,728	1,28	1,984	2,048
Spectrum efficiency as ITU	bit/s/Hz	0,109	0,205	0,328	0,369	0,273	0,423	0,437
Power efficiency as ITU	-	4,22%	4,30%	4,41%	4,26%	4,34%	3,77%	4,32%

7.1.3 Data service 128 kbps

Table 7.3: Link budget; Data 128 kbps

FORWARD LINK BUDGET		Handset	Handheld	Vehicular	Transportable	Handset	Handheld	Vehicular
Satellite Location	°E	10				10		
Orbital Height	Km	35786				35786		
Unique Scrambling code		no	no	no	no	no	no	no
Center spot		no	no	no	no	YES	YES	YES
Calculation of interference from spot n+2		yes	yes	yes	yes	yes	yes	yes
ACLR at 5 MHz (Spot n+1)	dB	21,0	21,0	21,0	21,0	21,0	21,0	21,0
Antenna C/I (at EOC) Spot n+2	dB	12,0	12,0	12,0	12,0	15,0	15,0	15,0
Max EIRP per spot (EOC)	dBW	71,0	71,0	71,0	71,0	75,0	75,0	75,0
Chip Rate	Mchip/s	3,840						
Chip SRC Roll-off Factor	-	0,22						
Full FDM Bandwidth	MHz	4,68	4,68	4,68	4,68	4,68	4,68	4,68
Data Rate	**bit/s**	128 000	128 000	128 000	128 000	128 000	128 000	128 000
Traffic Activity Factor	**-**	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Required Eb/(No+Io)	**dB**	3,40	3,40	3,40	3,40	3,40	3,40	3,40
UE elevation	°	30	30	30	30	30	30	30
Slant Range	Km	38611,2	38611,2	38611,2	38611,2	38611,2	38611,2	38611,2
Downlink Frequency	MHz	2200						
Availability (/year)	%	99,96						
Polarization (C/V/H)	C/V/H	Circular						
OBO and EIRP per code Calculation								
Total OBO	dB	-2						
Total OBOu	dB	-2,9	-2,9	-2,9	-2,9	-2,9	-2,9	-2,9
Signaling OBO	dB	-9,85	-9,85	-9,85	-9,85	-9,85	-9,85	-9,85
Common Physical Channels	dBW	61,15	61,15	61,15	61,15	65,15	65,15	65,15
Carrier Total EIRP for traffic per spot	dBW	67,18	67,18	67,18	67,18	71,18	71,18	71,18
On Board EIRP per SCCPCH (per traffic	dBW	60,19	57,64	55,72	55,14	60,39	59,42	59,42
Common Physical Channels Equivalent Traffic Codes	-	1,25	2,24	3,49	3,99	2,99	3,74	3,74
Losses (free space,rain, atmos.)	dB	191,11	191,11	191,11	191,11	191,11	191,11	191,11
UE Antenna Gain including polarisation losses	dBi	-3,0	1,0	4,0	14,0	-3,0	1,0	4,0
UE System Temp.	K	817,3	727,3	319,6	319,6	817,3	727,3	319,6
UE G/T	dB/K	-32,1	-27,6	-21,0	-11,0	-32,1	-27,6	-21,0
Thermal Noise Density, No	dBW/Hz	-199,5	-200,0	-203,6	-203,6	-199,5	-200,0	-203,6
Interference from adjacent spots	dBW	-147,0	-143,0	-140,0	-130,0	-1000,0	-1000,0	-1000,0
Interference from spot n+2 (Spain/Germany,	dBW	-138,0	-134,0	-131,0	-121,0	-137,0	-133,0	-130,0
Interference from 2ndary scrambling code	dBW	-1000,0	-1000,0	-1000,0	-122,0	-1000,0	-1000,0	-1000,0
Total interference per channel	dBW	-137,4	-133,4	-130,4	-118,1	-137,0	-133,0	-130,0
-10*LOG(Spreading Bandwidth)	dB/Hz	-65,8	-65,8	-65,8	-65,8	-65,8	-65,8	-65,8
Interference Density, Io	dBW/Hz	-203,3	-199,3	-196,3	-184,0	-202,8	-198,8	-195,8
10*log(No+Io)	dBW/Hz	-198,0	-196,6	-195,5	-183,9	-197,8	-196,3	-195,1
Rx Power Flux Density	dBW/m²	-102,5	-105,1	-107,0	-107,6	-102,3	-103,3	-103,3
Total Received PFD	dBW/m²/1 MHz	-100,4	-100,4	-100,4	-100,4	-96,4	-96,4	-96,4
DL C/No	dBHz	65,6	67,5	72,2	81,6	65,8	69,3	75,9
DL C/Io	dBHz	69,4	66,8	64,9	62,0	69,1	68,1	68,1
DL C/(No+Io)	dBHz	64,1	64,1	64,2	62,0	64,1	65,7	67,4
DL Eb/(No+Io)	**dB**	13,0	13,1	13,1	10,9	13,0	14,6	16,4
Eb/No Losses due to Satellite Non-Linearities	dB	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Eb/No Losses due to feeder link degradation (I	dB	0,2	0,2	0,2	0,2	0,2	0,2	0,2
Overall Link Eb/(No+Io)	**dB**	12,8	12,9	12,9	10,7	12,8	14,4	16,2
Total C/(N+I)	**dB**	-2,9	-2,8	-2,8	-4,9	-2,8	-1,3	0,5
SCCPCH Power level at UE antenna	dBW	-133,92	-132,47	-131,39	-121,97	-133,72	-130,69	-127,69
SCCPCH Power level at UE antenna	dBm	-103,92	-102,47	-101,39	-91,97	-103,72	-100,69	-97,69
Common channels power level at UE antenna	dBm	-102,96	-98,96	-95,96	-85,96	-98,96	-94,96	-91,96
Raw Margin	**dB**	9,4	9,5	9,5	7,3	9,4	11,0	12,8
Nb. Traffic Codes/Spot/Carrier	-	5,00	9,00	14,00	16,00	12,00	15,00	15,00
Capacity per spot per carrier	**Mbps**	0,64	1,152	1,792	2,048	1,536	1,92	1,92
Spectrum efficiency as ITU	bit/s/Hz	0,137	0,246	0,383	0,437	0,328	0,410	0,410
Power efficiency as ITU	-	5,27%	5,16%	5,15%	8,54%	5,21%	3,64%	2,42%

7.1.4 Data service 256 kbps

Table 7.4: Link budget; Data 256 kbps

FORWARD LINK BUDGET		Handset	Handheld	Vehicular	Transportable	Handset	Handheld	Vehicular
Satellite Location	°E	10				10		
Orbital Height	Km	35786				35786		
Unique Scrambling code		no	no	no	no	no	no	no
Center spot		no	no	no	no	YES	YES	YES
Calculation of interference from spot n+2		yes	yes	yes	yes	yes	yes	yes
ACLR at 5 MHz (Spot n+1)	dB	21,0	21,0	21,0	21,0	21,0	21,0	21,0
Antenna C/I (at EOC) Spot n+2	dB	12,0	12,0	12,0	12,0	15,0	15,0	15,0
Max EIRP per spot (EOC)	dBW	71,0	71,0	71,0	71,0	75,0	75,0	75,0
Chip Rate	Mchip/s	3,840						
Chip SRC Roll-off Factor	-	0,22						
Full FDM Bandwidth	MHz	4,68	4,68	4,68	4,68	4,68	4,68	4,68
Data Rate	**bit/s**	256 000	256 000	256 000	256 000	256 000	256 000	256 000
Traffic Activity Factor	**-**	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Required Eb/(No+Io)	**dB**	3,20	3,20	3,20	3,20	3,20	3,20	3,20
UE elevation	°	30	30	30	30	30	30	30
Slant Range	Km	38611,2	38611,2	38611,2	38611,2	38611,2	38611,2	38611,2
Downlink Frequency	MHz	2200						
Availability (/year)	%	99,96						
Polarization (C/V/H)	C/V/H	Circular						
OBO and EIRP per code Calculation								
Total OBO	dB	-2						
Total OBOu	dB	-2,9	-2,9	-2,9	-2,9	-2,9	-2,9	-2,9
Signaling OBO	dB	-9,85	-9,85	-9,85	-9,85	-9,85	-9,85	-9,85
Common Physical Channels	dBW	61,15	61,15	61,15	61,15	65,15	65,15	65,15
Carrier Total EIRP for traffic per spot	dBW	67,18	67,18	67,18	67,18	71,18	71,18	71,18
On Board EIRP per SCCPCH (per traffic	dBW	62,41	60,19	58,73	58,73	63,40	62,73	62,73
Common Physical Channels Equivalent Traffic Codes	-	0,75	1,25	1,74	1,74	1,50	1,74	1,74
Losses (free space,rain, atmos.)	dB	191,11	191,11	191,11	191,11	191,11	191,11	191,11
UE Antenna Gain including polarisation losses	dBi	-3,0	1,0	4,0	14,0	-3,0	1,0	4,0
UE System Temp.	K	817,3	727,3	319,6	319,6	817,3	727,3	319,6
UE G/T	dB/K	-32,1	-27,6	-21,0	-11,0	-32,1	-27,6	-21,0
Thermal Noise Density, No	dBW/Hz	-199,5	-200,0	-203,6	-203,6	-199,5	-200,0	-203,6
Interference from adjacent spots	dBW	-147,0	-143,0	-140,0	-130,0	-1000,0	-1000,0	-1000,0
Interference from spot n+2 (Spain/Germany,	dBW	-138,0	-134,0	-131,0	-121,0	-137,0	-133,0	-130,0
Interference from 2ndary scrambling code	dBW	-1000,0	-1000,0	-1000,0	-1000,0	-1000,0	-1000,0	-1000,0
Total interference per channel	dBW	-137,4	-133,4	-130,4	-120,4	-137,0	-133,0	-130,0
-10*LOG(Spreading Bandwidth)	dB/Hz	-65,8	-65,8	-65,8	-65,8	-65,8	-65,8	-65,8
Interference Density, Io	dBW/Hz	-203,3	-199,3	-196,3	-186,3	-202,8	-198,8	-195,8
10*log(No+Io)	dBW/Hz	-198,0	-196,6	-195,5	-186,2	-197,8	-196,3	-195,1
Rx Power Flux Density	dBW/m²	-100,3	-102,5	-104,0	-104,0	-99,3	-100,0	-100,0
Total Received PFD	dBW/m²/1 MHz	-100,4	-100,4	-100,4	-100,4	-96,4	-96,4	-96,4
DL C/No	dBHz	67,8	70,1	75,2	85,2	68,8	72,6	79,2
DL C/Io	dBHz	71,6	69,4	67,9	67,9	72,1	71,4	71,4
DL C/(No+Io)	dBHz	66,3	66,7	67,2	67,8	67,1	69,0	70,8
DL Eb/(No+Io)	**dB**	12,2	12,6	13,1	13,7	13,0	14,9	16,7
Eb/No Losses due to Satellite Non-Linearities	dB	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Eb/No Losses due to feeder link degradation (I	dB	0,2	0,2	0,2	0,2	0,2	0,2	0,2
Overall Link Eb/(No+Io)	**dB**	12,0	12,4	12,9	13,5	12,8	14,7	16,5
Total C/(N+I)	**dB**	-0,6	-0,2	0,3	0,9	0,2	2,1	3,8
SCCPCH Power level at UE antenna	dBW	-131,70	-129,92	-128,38	-118,38	-130,71	-127,38	-124,38
SCCPCH Power level at UE antenna	dBm	-101,70	-99,92	-98,38	-88,38	-100,71	-97,38	-94,38
Common channels power level at UE antenna	dBm	-102,96	-98,96	-95,96	-85,96	-98,96	-94,96	-91,96
Raw Margin	**dB**	8,8	9,2	9,7	10,3	9,6	11,5	13,3
Nb. Traffic Codes/Spot/Carrier	-	3,00	5,00	7,00	7,00	6,00	7,00	7,00
Capacity per spot per carrier	**Mbps**	0,768	1,28	1,792	1,792	1,536	1,792	1,792
Spectrum efficiency as ITU	bit/s/Hz	0,164	0,273	0,383	0,383	0,328	0,383	0,383
Power efficiency as ITU	-	6,33%	5,74%	5,15%	4,42%	5,21%	3,40%	2,25%

7.1.5 Data service 384 kbps

Table 7.5: Link budget; Data 384 kbps

FORWARD LINK BUDGET		Handset	Handheld	Vehicular	Transportable	Handset	Handheld	Vehicular
Satellite Location	°E	10				10		
Orbital Height	Km	35786				35786		
Unique Scrambling code		no	no	no	no	no	no	no
Center spot		no	no	no	no	YES	YES	YES
Calculation of interference from spot n+2		yes	yes	yes	yes	yes	yes	yes
ACLR at 5 MHz (Spot n+1)	dB	21,0	21,0	21,0	21,0	21,0	21,0	21,0
Antenna C/I (at EOC) Spot n+2	dB	12,0	12,0	12,0	12,0	15,0	15,0	15,0
Max EIRP per spot (EOC)	dBW	71,0	71,0	71,0	71,0	75,0	75,0	75,0
Chip Rate	Mchip/s	3,840						
Chip SRC Roll-off Factor	-	0,22						
Full FDM Bandwidth	MHz	4,68	4,68	4,68	4,68	4,68	4,68	4,68
Data Rate	**bit/s**	384 000	384 000	384 000	384 000	384 000	384 000	384 000
Traffic Activity Factor	**-**	1,0	1,0	1,0	1,0	1,0	1,0	1,0
Required Eb/(No+Io)	**dB**	3,70	3,70	3,70	3,70	3,70	3,70	3,70
UE elevation	°	30	30	30	30	30	30	30
Slant Range	Km	38611,2	38611,2	38611,2	38611,2	38611,2	38611,2	38611,2
Downlink Frequency	MHz	2200						
Availability (/year)	%	99,96						
Polarization (C/V/H)	C/V/H	Circular						
OBO and EIRP per code Calculation								
Total OBO	dB	-2						
Total OBOu	dB	-2,9	-2,9	-2,9	-2,9	-2,9	-2,9	-2,9
Signaling OBO	dB	-9,85	-9,85	-9,85	-9,85	-9,85	-9,85	-9,85
Common Physical Channels	dBW	61,15	61,15	61,15	61,15	65,15	65,15	65,15
Carrier Total EIRP for traffic per spot	dBW	67,18	67,18	67,18	67,18	71,18	71,18	71,18
On Board EIRP per SCCPCH (per traffic	dBW	64,17	62,41	61,16	60,19	65,16	63,40	62,73
Common Physical Channels Equivalent Traffic Codes	-	0,50	0,75	1,00	1,25	1,00	1,50	1,74
Losses (free space,rain, atmos.)	dB	191,11	191,11	191,11	191,11	191,11	191,11	191,11
UE Antenna Gain including polarisation losses	dBi	-3,0	1,0	4,0	14,0	-3,0	1,0	4,0
UE System Temp.	K	817,3	727,3	319,6	319,6	817,3	727,3	319,6
UE G/T	dB/K	-32,1	-27,6	-21,0	-11,0	-32,1	-27,6	-21,0
Thermal Noise Density, No	dBW/Hz	-199,5	-200,0	-203,6	-203,6	-199,5	-200,0	-203,6
Interference from adjacent spots	dBW	-147,0	-143,0	-140,0	-130,0	-1000,0	-1000,0	-1000,0
Interference from spot n+2 (Spain/Germany,	dBW	-138,0	-134,0	-131,0	-121,0	-137,0	-133,0	-130,0
Interference from 2ndary scrambling code	dBW	-1000,0	-1000,0	-1000,0	-1000,0	-1000,0	-1000,0	-1000,0
Total interference per channel	dBW	-137,4	-133,4	-130,4	-120,4	-137,0	-133,0	-130,0
-10*LOG(Spreading Bandwidth)	dB/Hz	-65,8	-65,8	-65,8	-65,8	-65,8	-65,8	-65,8
Interference Density, Io	dBW/Hz	-203,3	-199,3	-196,3	-186,3	-202,8	-198,8	-195,8
10*log(No+Io)	dBW/Hz	-198,0	-196,6	-195,5	-186,2	-197,8	-196,3	-195,1
Rx Power Flux Density	dBW/m²	-98,6	-100,3	-101,6	-102,5	-97,6	-99,3	-100,0
Total Received PFD	dBW/m²/1 MHz	-100,4	-100,4	-100,4	-100,4	-96,4	-96,4	-96,4
DL C/No	dBHz	69,5	72,3	77,6	86,6	70,5	73,3	79,2
DL C/Io	dBHz	73,4	71,6	70,3	69,4	73,9	72,1	71,4
DL C/(No+Io)	dBHz	68,0	68,9	69,6	69,3	68,9	69,6	70,8
DL Eb/(No+Io)	**dB**	12,2	13,1	13,8	13,4	13,0	13,8	14,9
Eb/No Losses due to Satellite Non-Linearities	dB	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Eb/No Losses due to feeder link degradation (I	dB	0,2	0,2	0,2	0,2	0,2	0,2	0,2
Overall Link Eb/(No+Io)	**dB**	12,0	12,9	13,6	13,2	12,8	13,6	14,7
Total C/(N+I)	**dB**	1,1	2,0	2,7	2,4	2,0	2,7	3,8
SCCPCH Power level at UE antenna	dBW	-129,94	-127,70	-125,95	-116,92	-128,95	-126,71	-124,38
SCCPCH Power level at UE antenna	dBm	-99,94	-97,70	-95,95	-86,92	-98,95	-96,71	-94,38
Common channels power level at UE antenna	dBm	-102,96	-98,96	-95,96	-85,96	-98,96	-94,96	-91,96
Raw Margin	**dB**	8,3	9,2	9,9	9,5	9,1	9,9	11,0
Nb. Traffic Codes/Spot/Carrier	-	2,00	3,00	4,00	5,00	4,00	6,00	7,00
Capacity per spot per carrier	**Mbps**	0,768	1,152	1,536	1,92	1,536	2,304	2,688
Spectrum efficiency as ITU	bit/s/Hz	0,164	0,246	0,328	0,410	0,328	0,492	0,574
Power efficiency as ITU	-	6,33%	5,16%	4,41%	4,73%	5,21%	4,37%	3,38%

7.2 System capacity

System capacity is summarized for at spot EOC as well as spot center for an exemplary satellite that provides 71 dBW at EOC.

System capacity is also given for rural environment without margin for shadowing, i.e. constant LOS view of the satellite. This covers, among others, aeronautical UE configuration system capacity.

Audio service traffic activity factor is 0,5. This allows to map additional channelization codes on a secondary scrambling code while ensuring the link margin is still positive for channelization codes mapped to both primary and secondary scrambling codes.

7.2.1 Orthogonality factor

An important point to note is the degradation of the orthogonality factor in presence of IMRs.

In effect, for satellite only propagation channels, due to the low level of multipath components to be compared to the main path (see propagation channels in clause 6.1), the orthogonality factor is well preserve. This is true even for NLOS situations (excepted urban ITU C). It is one major advantage of satellite propagation channels to be compared to terrestrial radio environments. Orthogonality factors for ITU satellite propagation channels is presented in the table 7.6:

Table 7.6: Orthogonality factor (α); ITU satellite propagation channels

Propagation model	α
ITU A LOS (rural)	0,991
ITU A NLOS (rural)	0,951
ITU B LOS (sub-urban)	0,989
ITU B NLOS (sub-urban)	0,909
ITU C LOS (urban)	0,921
ITU C NLOS (urban)	0,473

The introduction of IMRs degrades the orthogonality factor, to a dramatic level with transparent IMRs due to the high number of artificial multi-paths introduced:

Table 7.7: Orthogonality factor (α); Combined satellite + IMRs propagation channels

Propagation model	α	Applicability
High power IMR Low power IMR	0,284 0,277	Transparent IMR
Pedestrian A Vehicular A	0,838 0,506	Regenerative IMR

7.2.2 Rural environment with shadowing

Table 7.8: System capacity; Rural with shadowing

	EOC			Center spot		
	Capacity/ carrier/ spot (kbps)	Nb codes/ spot/ carrier	Link margin dB	Capacity/ carrier/ spot (kbps)	Nb codes/ spot/ carrier	Link margin dB
Handset						
8 kbps	352	88	9,6	872	218	9,6
64 kbps	512	8	9,7	1 280	20	9,6
128 kbps	640	5	9,4	1 536	12	9,4
256 kbps	768	3	8,8	1 536	6	9,6
384 kbps	768	2	8,3	1 536	4	9,1
Handheld						
8 kbps	740	185	9,6	1 088	272	9,6
64 kbps	960	15	9,7	1 984	31	10,2
128 kbps	1 152	9	9,5	1 920	15	11,0
256 kbps	1 280	5	9,2	1 792	7	11,5
384 kbps	1 152	3	9,2	2 304	6	9,9
Vehicular						
8 kbps	1 056	264	9,6	1 136	284	9,6
64 kbps	1 536	24	9,6	2 048	32	9,6
128 kbps	1 792	14	9,5	1 920	15	12,8
256 kbps	1 792	7	9,7	1 792	7	13,3
384 kbps	1 536	4	9,9	2 688	7	11,0
Transportable						
8 kbps	1 084	271	9,6	1 148	287	9,6
64 kbps	1 728	27	9,7	2 048	32	10,0
128 kbps	2 048	16	7,3	1 920	15	13,4
256 kbps	1 792	7	10,3	1 792	7	13,9
384 kbps	1 920	5	9,5	2 688	7	11,6

7.2.3 Rural environment with constant LOS view of the satellite

Link margin is decreased to 2,1 dB which is the margin required to cover UE demodulation performance degradation due to mobility in rural LOS conditions (ITU A LOS).

Table 7.9: System capacity; Rural LOS

	EOC			Center spot		
	Capacity/ carrier/ spot (kbps)	**Nb codes/ spot/ carrier**	**Link margin dB**	**Capacity/ carrier/ spot (kbps)**	**Nb codes/ spot/ carrier**	**Link margin dB**
Handset						
8 kbps	1 016	254	5,0	1 016	254	8,9
64 kbps	2 176	34	2,4	2 560	40	2,1
128 kbps	2 176	17	2,6	2 560	20	2,4
256 kbps	2 048	8	3,0	2 560	10	2,1
384 kbps	2 688	7	2,8	3 072	8	3,1
Handheld						
8 kbps	1 016	254	8,2	1 192	298	7,5
64 kbps	2 432	38	2,4	2 688	42	2,1
128 kbps	2 432	19	2,6	2 688	21	2,4
256 kbps	2 304	9	2,9	2 560	10	2,7
384 kbps	3 072	8	2,5	3 072	8	4,2
Vehicular						
8 kbps	1 132	283	8,0	1 292	323	6,9
64 kbps	2 560	40	2,4	2 752	43	2,1
128 kbps	2 688	21	2,0	2 816	22	2,1
256 kbps	2 560	10	2,3	2 560	10	3,0
384 kbps	3 072	8	3,4	3 456	9	2,3
Transportable						
8 kbps	1 188	297	7,5	1 320	330	6,7
64 kbps	2 624	41	2,2	2 752	43	2,2
128 kbps	2 688	21	2,2	2 816	22	2,2
256 kbps	2 560	10	2,4	2 560	10	3,0
384 kbps	3 072	8	3,7	3 456	9	2,4

7.2.4 Combined satellite and IMR environment

IMRs deployment allow to reduce the path blockage situations in urban environments (buildings, etc.), at the expense of capacity per carrier due to the loss of orthogonality coming from high level of multi-paths components in terrestrial propagation environment and due to the limited number of fingers of the UE Rake receiver.

The tables below present capacity per carrier with both transparent and regenerative IMRs deployment, the regenerative IMRs being allocated distinct scrambling codes which means activation of soft combining at UE receiver, in case UE number of Rake receiver fingers is limited to 6.

Table 7.10: Capacity per carrier; IMR environment; 64 kbps

Data rate	**64 kbps**		**Capacity per carrier (kbps)**	**Nb. of codes**
Speed	IMR Type	Channel		
3 km/h	Transparent IMR	Low Power	192	3
		High Power	192	3
	Regenerative IMR	Pedestrian A	256	4
		Vehicular A	320	5
50 km/h	Transparent IMR	Low Power	448	7
		High Power	448	7
	Regenerative IMR	Pedestrian A	896	14
		Vehicular A	768	12

Table 7.11: Capacity per carrier; IMR environment; 128 kbps

Data rate	128 kbps		Capacity per carrier (kbps)	Nb. of codes
Speed	IMR Type	Channel		
3 km/h	Transparent IMR	Low Power	256	2
		High Power	256	2
	Non-transparent IMR	Pedestrian A	256	2
		Vehicular A	384	3
50 km/h	Transparent IMR	Low Power	512	4
		High Power	512	4
	Non-transparent IMR	Pedestrian A	896	7
		Vehicular A	768	6

7.2.5 Hierarchical services structure

At this moment, it is recommended to structure broadcast services hierarchically: high priority data is mapped to low data rate channels (for example: 8 kbps or 64 kbps) while low priority data is mapped to high data rate channel. An illustrative example is: textual essential data sent over 8 kbps channel, images sent over 128 or 256 kbps.

UE equipment decodes the low or high data rate channel depending on its reception capabilities and its radio environment (see system capacity evaluation).

8 Technology design constraints

8.1 Doppler frequency shift

8.1.1 Doppler shift due to satellite movement

Considering GEO satellite configuration, a speed of 3m/s for the movement of the satellite (stabilization of the North-South inclination of about 0,07°) and $\cos(\alpha) = 1$, the maximum theorical Doppler frequency shift is calculated at upper limit of MSS core frequency band. The Doppler for average elevations of 15, 30 and 45° is also given for information.

Table 8.1: Doppler frequency shift due to satellite movement (GEO case)

	Max value	15°	30°	45°
Doppler frequency shift	22 Hz	21 Hz	19 Hz	15,5 Hz

The Doppler frequency shift due to the GEO satellite movement is negligible to be compared to the one due to UE movement (see clause 8.1.2). Thus it can easily be compensated with standard 3GPP chipsets.

For LEO/HEO/MEO constellations, it is envisaged to append a dedicated Doppler compensation module to UE.

8.1.2 Doppler shift due to UE movement

Depending on the maximum UE speed, the maximum theorical Doppler frequency shift is as follows (at upper limit of MSS core frequency band). The Doppler for average elevations of 15, 30 and 45° is also given for information:

Table 8.2: Maximum Doppler frequency shift due to UE movement

UE velocity	Max value	15°	30°	45°
5 000 km/h (aeronautical future)	10 185 Hz	9 838 Hz	8 820 Hz	7 201 Hz
1 000 km/h (aeronautical)	2 037 Hz	1 967 Hz	1 764 Hz	1 440 Hz
500 km/h	1 018 Hz	983 Hz	881,6 Hz	720 Hz
120 km/h	244 Hz	235,6 Hz	211 Hz	172,5 Hz
3 km/h	6,1 Hz	5,9 Hz	5,2 Hz	4,3 Hz

The most constraining is aeronautical environment concerning Doppler frequency shift. This constraints may drive to add a Doppler compensation module to the UE and the gateway for use in aeronautical environment.

8.2 Interoperability

8.2.1 Dual mode UEs

To use W-CDMA UTRA FDD with satellite environment means essential parameters are made common between satellite and terrestrial systems. Consequently, most of RF and base-band circuits in the UE can be shared by the two operation modes. The UE antenna is also shared by the two operation modes for the handset configuration when operated under IMRs coverage. This should allow for small and light-weight dual mode UEs.

Dual mode UEs with 2nd generation systems, e.g. GSM or GMR and 2nd generation services are also supported.

8.2.2 Intermediate Module Repeaters (IMR)

IMR can be built with UTRAN Node B equipment. Co-location with terrestrial Node Bs is possible for system deployment integration.

8.2.3 Inter-system handover

The proposed radio interface eases inter-system handover:

- with 2nd generation systems (e.g. GSM or GMR) thanks to compressed mode;
- with terrestrial UMTS thanks to the use of the same radio interface (same waveform, same protocol architecture).

8.2.4 Compatibility with existing systems

Since the radio interface is not new but based on terrestrial UMTS, it is highly recommended to reuse terrestrial UMTS components.

Furthermore, it presents no problem for connection to terrestrial 3GPP infrastructure thanks to the use of standardized transport interfaces: Iub, Iur and Iu interfaces are kept unchanged from 3GPP standards.

8.3 Performance enhancement features

For the space segment, communication payload on-board satellite may implement techniques that enhance system performance, e.g.:

- transparent analogue connectivity between spots and/or frequency channels: this allows connectivity between coverage areas, thus allowing to easily dispatch S-MBMS services to spots;
- regenerative payload: on-board base band processing signal demodulation/re-modulation and decoding/re-encoding may be implemented in order to increase link level performance. Link budget calculations (see clause 7.1) are based on the assumption that the feeder link has little impact on link level performance. Thus regenerative payload seems to be of interest in case on-board connectivity only;
- active antennas for coverage re-scheduling.

For the terrestrial segment, candidate techniques for system performance enhancement are:

- additionally to Multi User Detection (MUD) which feasibility is commonly agreed for the uplink direction, applicability to the downlink direction is being considered. In effect, implementing interference cancellation at the UE receiver means to inform the UE about scrambling code, thus allowing for adjacent spot and/or secondary scrambling code interference cancellation. A major focus is to be pointed on the UE implementation cost;
- receiver diversity at the UE level, i.e. dual antenna at UE, for portable, vehicular and transportable configurations;
- time diversity;
- higher level modulation for the downlink direction can be considered, with restriction due to satellite power capacity constraints;
- optimized code allocation strategy.

8.4 System flexibility

The radio interface allows for system flexibility such as:

- dynamic spot redirection: a spot coverage may be redirected to a regional area where more capacity is required;
- dynamic spot power redistribution: satellite power can be redistributed between spots according to varying capacity requirement;
- satellite diversity.

9 Conclusion

The present document has presented the feasibility of using W-CDMA as a satellite radio interface. Satellite Multimedia Broadcast/Multicast Service enlarges capacity of terrestrial networks. The main system characteristics can be summarized as:

- UMTS terrestrial networks interoperability;
- large area coverage, particularly convenient for services such as broadcast/multicast services;
- suitable to complement terrestrial coverage in areas where:
  - terrestrial systems have not been deployed for business attractiveness reasons; or
  - terrestrial coverage requires capacity complement; or
  - terrestrial system has suffered environmental damages (crisis conditions);
- in the absence of Intermediate Module Repeaters, possibility to operate under obstructed environment and some short indoor penetration;
- intermediate Module Repeaters can extend system capacity in urban and indoor coverage areas, in the MSS frequency band;
- reuse of terrestrial equipment, which allows economies of scale.

The major adaptation expected from 3GPP equipment for operation in satellite environment is RF agility to MSS frequency band.

Annex A: Downlink reference measurement channels

Test services adopted hereafter are similar to 3GPP ones, i.e. audio 8 kbps and data 64/128/256/384 kbps (see [11] and [12]), with the difference that they are mapped to FACH.

A.1 Audio 8 kbps service

This test service concerns broadcasting of basic audio service. The parameters for the 8 kbps audio broadcast service are specified in table A.1 the channel coding for information is shown in figure A.1.

Table A.1: Parameters for 8 kbps test service

Parameter	
Information bit rate	8 kbps
S-CCPCH	15 ksps
Slot format #i	2
TFCI	On
TFCI/pilot to data fields power offsets	0 dB
Puncturing	2,17 %
Transport channel number	1
Transport block size	160 bits
Transport block set size	160 bits
Transmission time interval	20 ms
Type of error protection	Convolution Coding
Coding rate	1/3
Rate matching attribute	256
Size of CRC	16
Position of TrCH in radio frame	Fixed

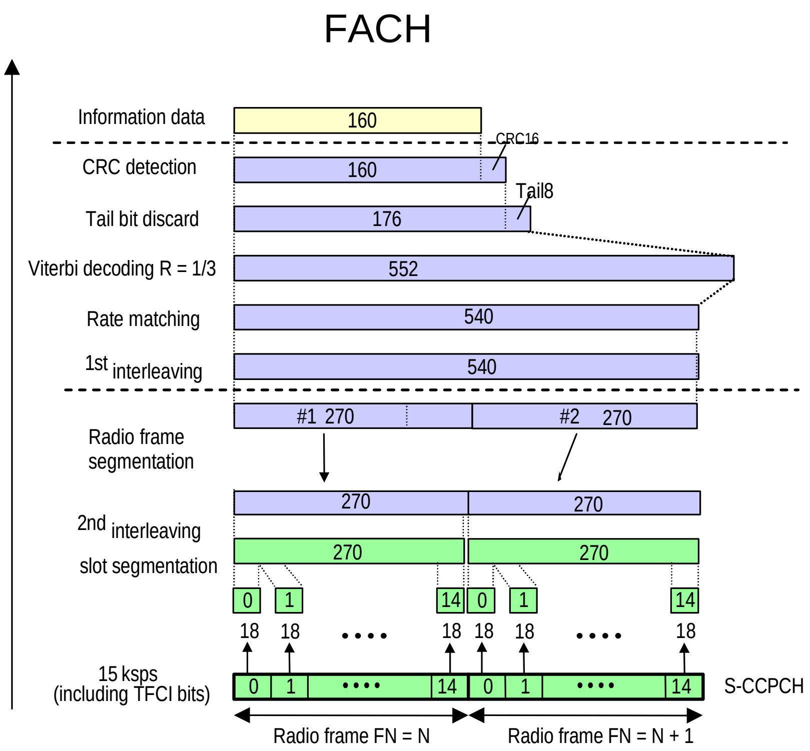


Figure A.1: Channel coding and multiplexing example for 8 kbps data

A.2 Data 64 kbps service

The parameters for the 64 kbps data service are specified in table A.2. The channel coding for information is shown in figure A.2.

Table A.2: Parameters for 64 kbps test service

Parameter	
Information bit rate	64 kbps
S-CCPCH	120 ksps
Slot format #i	11
TFCI	On
TFCI/pilot to data fields power offsets	0 dB
Repetition	11,1 %
Transport channel number	1
Transport block size	1 280
Transport block set size	1 280
Transmission time interval	20 ms
Type of error protection	Turbo Coding
Coding rate	1/3
Rate matching attribute	256
Size of CRC	16
Position of TrCH in radio frame	Fixed

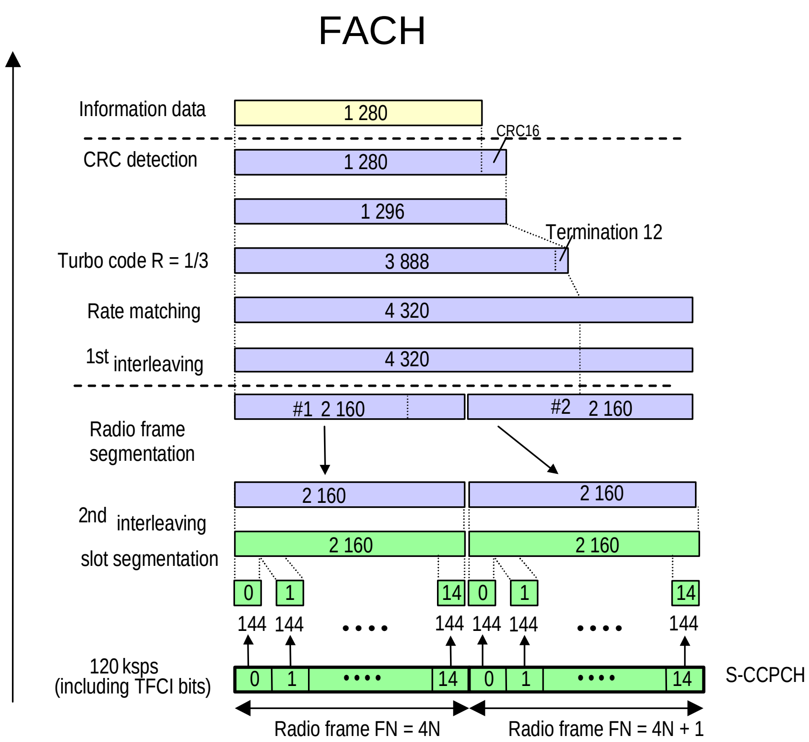


Figure A.2: Channel coding and multiplexing example for 64 kbps data

A.3 Data 128 kbps service

The parameters for the 128 kbps data service are specified in table A.3. The channel coding for information is shown in figure A.3.

Table A.3: Parameters for 128 kbps test service

Parameter	
Information bit rate	128 kbps
S-CCPCH	240 ksps
Slot format #i	12
TFCI	On
TFCI/pilot to data fields power offsets	0 dB
Repetition	21,58 %
Transport channel number	1
Transport block size	10 240
Transport block set size	10 240
Transmission time interval	80 ms
Type of error protection	Turbo Coding
Coding rate	1/3
Rate matching attribute	256
Size of CRC	16
Position of TrCH in radio frame	fixed

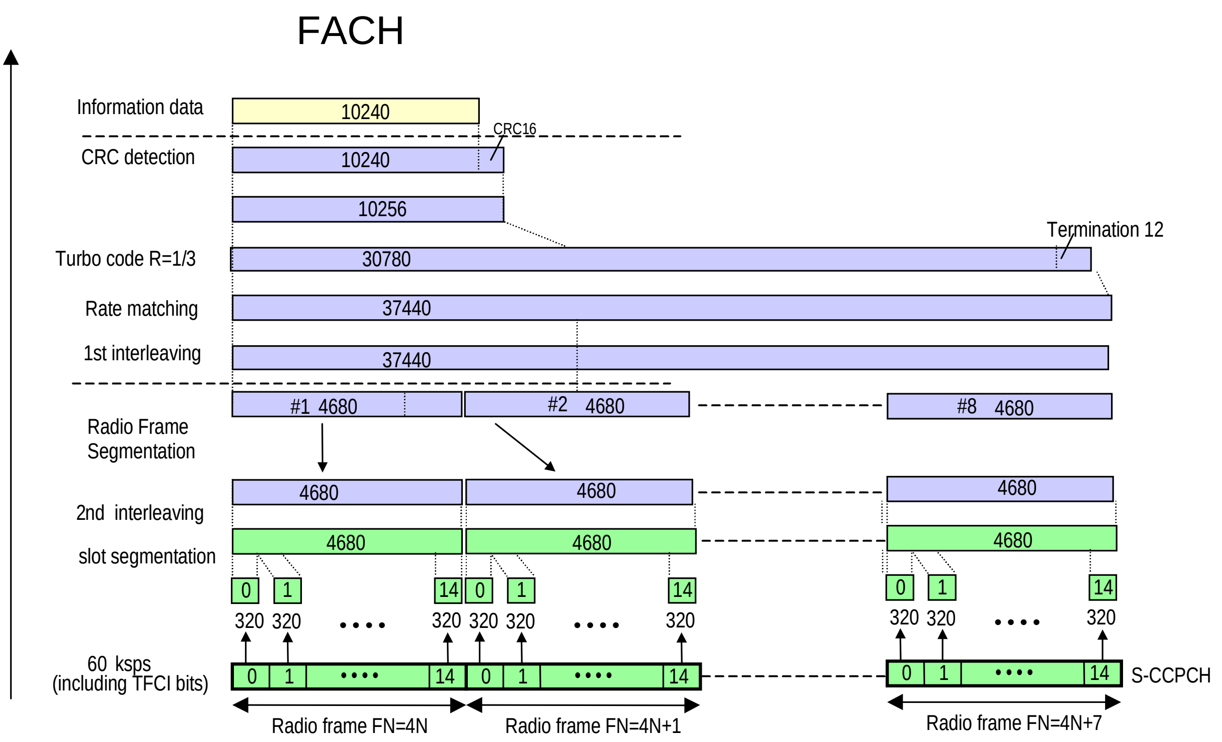


Figure A.3: Channel coding and multiplexing example for 128 kbps data

A.4 Data 256 kbps service

The parameters for the 256 kbps data service are specified in table A.4. The channel coding for information is shown in figure A.4.

Table A.4: Parameters for 256 kbps test service

Parameter	
Information bit rate	256 kbps
S-CCPCH	480 ksps
Slot format #i	14
TFCI	On
TFCI/pilot to data fields power offsets	0 dB
Repetition	22,5 %
Transport channel number	1
Transport block size	2 560
Transport block set size	2 560
Transmission time interval	10 ms
Type of error protection	Turbo Coding
Coding rate	1/3
Rate matching attribute	256
Size of CRC	16
Position of TrCH in radio frame	fixed

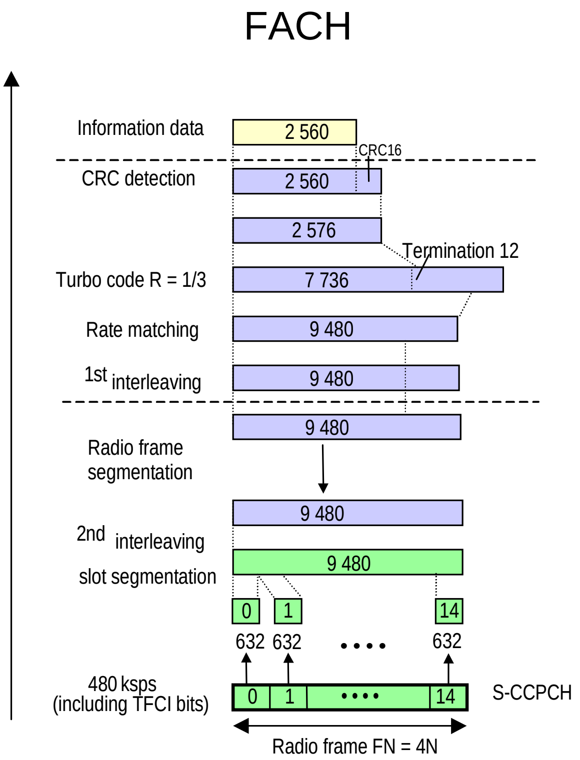


Figure A.4: Channel coding and multiplexing example for 256 kbps data

A.5 Data 384 kbps service

The parameters for the 384 kbps data service are specified in table A.5. The channel coding for information is shown in figure A.5.

Table A.5: Parameters for 384 kbps test service

Parameter	
Information bit rate	384 kbps
S-CCPCH	480 ksps
Slot format #i	15
TFCI	On
TFCI/pilot to data fields power offsets	0 dB
Puncturing	20,1 %
Transport channel number	1
Transport block size	3 840
Transport block set size	3 840
Transmission time interval	10 ms
Type of error protection	Turbo Coding
Coding rate	1/3
Rate matching attribute	256
Size of CRC	16
Position of TrCH in radio frame	fixed

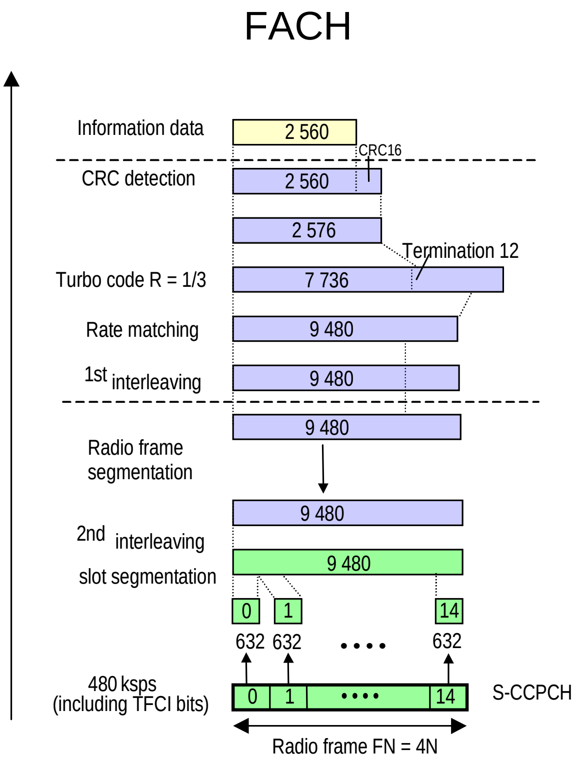


Figure A.5: Channel coding and multiplexing example for 384 kbps data

Annex B: Comparison of S-MBMS performance and system radio capacity with and without soft combining in IMR environment

B.1 Introduction

The present annex intends to present S-MBMS performance and system radio capacity with and without soft combining.

Soft combining is implemented in 3G UE for MBMS reception on several distinct scrambling code. This process is similar to the so-call soft handover commonly used in CDMA systems.

This technique may be applied for reception of S-MBMS:

- from several spots (each spot with a distinct scrambling code);
- from several IMRs when IMRs are allocated distinct scrambling codes (non-transparent IMRs).

The present annex firstly resumes radio resource code allocation, macro-diversity mechanisms and propagation behaviour, i.e. multi-path diversity. Then 3GPP UE capabilities are reminded. Finally, performances and system capacity applied to several IMRs radio resource allocation strategies (transparent and non-transparent IMRs) are presented.

B.2 References

[A] ETSI TR 102 277: "Satellite Earth Stations and Systems (SES); Satellite Component of UMTS/IMT-2000; Satellite Component for Multimedia Broadcast/Multicast Service (MBMS); W-CDMA Radio Interface".

[B] IEEE Vol.2, n°4, July 2003: "Characterising the Orthogonality Factor in WCDMA Downlink".

[C] IEE CNF N° 494, 25-27: "The Downlink Orthogonality Factors Influence on WCDMA System Performance"(June 2003).

[D] IEEE 2002: "The Downlink Orthogonality Factors Influence on WCDMA System Performance".

[E] 3GPP R1-041496: "Support for MBMS Soft Combining in Layer 1 Specifications" (25.214CR356r1(Rel-6, B)).

[F] IST 2000-25030 (Satin): "Simulation Results and Evaluation" (Deliverable No. 7).

B.3 3GPP Radio Resource Management

Basically, a WCDMA network can be deployed with only 1 frequency: all User Equipment (UE) use the same frequency simultaneously in all the operator's cells. In order to allow multiple access, a spreading code is applied on the data streams (hence the name CDMA: Code Division Multiple Access).

Hard handover (i.e. the switch to another frequency) is avoided as much as possible. Instead, the so called soft combining is used. With this soft combining, there is no break in the radio path. This is achieved by macro diversity: when appropriate (e.g. when the UE is on a boundary between 2 cells), the UE receives MBMS channels from two (or three) cells simultaneously, on the same frequency.

B.3.1 Downlink code allocation

In 3GPP WCDMA, codes are used in 2 different ways: as **channelization codes** and as **scrambling codes**.

In downlink, the channelization codes are allocated to individual physical channels and are used to distinguish the different users (or groups for broadcast/multicast) services.

The scrambling codes are allocated per cell and are used to improve the cross-correlation properties of the channelization codes (reducing interference between different cells).

Each cell has its own set of channelization codes, i.e. code tree (see below), to be used in downlink. With each code tree, there is an associated scrambling code, each cell has its own scrambling code. This allows to allocate the same downlink channelization code to 2 different physical channels in 2 neighbouring cells, thus facilitating the downlink code tree management done at cell level.

The channelization codes of the figure B.1 are Orthogonal Variable Spreading Factor (OVSF) codes that preserve the orthogonality between different physical channels. The OVSF codes can be defined using the code tree below:

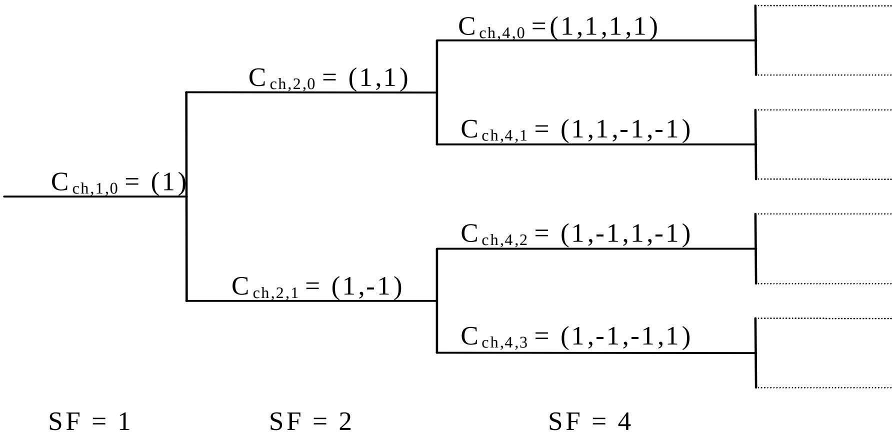


Figure B.1: Code-tree for generation of Orthogonal Variable Spreading Factor (OVSF) codes

The channelization codes are uniquely described as $C_{ch,SF,k}$, where SF is the spreading factor of the code and k is the code number, $0 \leq k \leq SF-1$, $4 \leq SF \leq 512$. Each level in the code tree defines channelization codes of length SF, corresponding to a spreading factor of SF in the figure B.1.

The common radio resource to be used by all users/services is power since a frequency reuse of one is used for all bearer services. There is no need to tightly plan scrambling codes (or code phase) since the number of codes is sufficiently large. No inter base-station (Node B) synchronisation is needed.

Each cell is allocated a primary scrambling code, which represents the signature of the cell. The downlink channels scrambled with the cell scrambling code are distinguished from each other by the channelization code they are allocated. All the channelization codes of the tree are orthogonal at the satellite/IMR antenna transmission point.

Another channelization code tree can be built under a secondary scrambling code (3GPP allows up to 15 secondary scrambling codes per cell), but there is no orthogonality with the channelization codes tree under the primary scrambling code: this produces a large amount of interference and thus is used only in very particular situations (smart antennas, etc.).

Assuming no secondary scrambling code is used, this primary scrambling code is the one used to scramble all the downlink channels.

As already mentioned above, cells are not necessarily inter-synchronised: codes from an IMR cell are not orthogonal to the ones of the adjacent IMR cells at UE antenna connector.

B.3.2 Macro-diversity

When a UE receives S-MBMS services, it receives energy transmitted by adjacent cell signals, those signals are seen as interference. This more especially as codes from neighbouring cells are not orthogonal.

3GPP defines procedures for allocating a radio resource from adjacent cells to an MBMS service, i.e. a channelization code carried on distinct scrambling codes.

All the cells involved in the MBMS service transmit the same information. UE is informed by the network to combine the corresponding scrambling codes. Then energy from adjacent cells becomes constructive instead of destructive to be compared to the absence of adjacent cells signal combining.

This process is the so-called MBMS soft combining, also often referred as macro-diversity mechanism. It is used to describe processing of multiple signals carried over a given frequency and several scrambling codes, i.e. multi-code combining. It is applicable to S-CCPCH for Release 6 and to S-CCPCH (see clause 5.2).

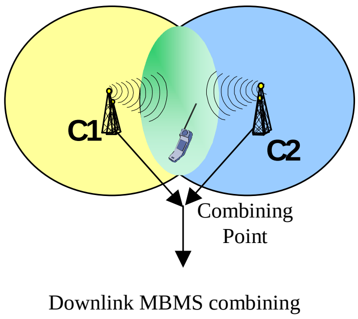


Figure B.2: Macro-diversity; MBMS combining

3GPP specifies that UE should be capable of combining up to 3 cells' scrambling codes for MBMS.

UE reception window length is time limited, so that radio infrastructure adjusts Node Bs transmission timing in order to guarantee UE receives multiple signals within its receiver time window. This is managed by RNC (Radio Network Controller), related information is transmitted to Node B at S-CCPCH radio links setup, through NBAP protocol over the standardised Iub interface (between Node B and RNC).

B.4 Propagation

B.4.1 Multi-path diversity

Signal propagation is affected by multiple reflections at hills, buildings, etc., as illustrated in the figure B.3:

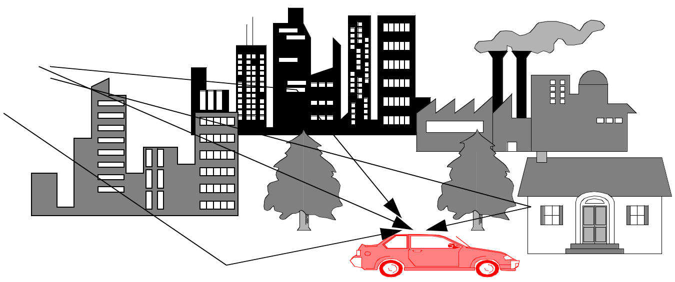


Figure B.3: Multi-path diversity

Signal carried arrives at UE at different time instants and is split into main path (the one carrying most energy) and multi-paths. The multi-paths are time separated to main path with various delays, i.e. delay spread. Typical delays are: 1 µs in urban and sub-urban environments, up to 20 µs in hilly areas (mountains, etc.).

When transparent IMRs (i.e. repeating with the same scrambling code than the satellite) are deployed, artificial multi-paths are generated. The multi-path components with a delay which fits to UE receiver window length (typically limited to 20 µs) are potentially constructive while the ones exceeding this delay are destructive.

Multi-path diversity is a term used to describe effect of multi-paths of a signal carried over a given frequency and scrambling code.

It is applicable to every type of physical channel: P-CCPCH (carrying BCH i.e. system related information), S-CCPCH (carrying FACH, i.e. MBMS traffic) and DPCH (carrying dedicated point-to-point communications).

B.4.2 Impact on code orthogonality

S-UMTS WCDMA operates at a high chip rate (3.84 Mcps), thus several multi-path components can be resolved at the UE receiver. The multi-paths provide a diversity gain through coherent Rake combining, but also introduces inter-path interference. This drives to degradation of downlink code orthogonality, causes an increase of intra-cell interference and has a direct impact on WCDMA system performance.

The degradation is quantified by the orthogonality factor, denoted α. For channels with N independent Rayleigh multi-paths, and Rake Receiver performing optimal combining (all the multi-paths are combined), α is approximated by:

$$\alpha = b_1 - b_2 \cdot \frac{\sum_{i=1}^{N} a_i^2}{\left(\sum_{i=1}^{N} a_i\right)^2}$$

In case Rake receiver can not combine all the multi-paths, the orthogonality factor degradation can be approximated by:

$$\alpha = 1 - \left[\sum_{f=1}^{F} \frac{\left|a_f\right|^2}{\sum_{j \neq f}^{N} \left|a_j\right|^2}\right]^{-1},$$

with F: number of multi-path combined by Rake Receiver.

In order to compare transparent and non-transparent IMRs propagation environments, the orthogonality factor has been calculated for propagation channels extracted from [F] where Low power IMR channel profile was based on ITU channel Pedestrian A and High power IMR was based on vehicular A.

The calculated orthogonality factor for transparent and non-transparent IMRs is:

Table B.1: Orthogonality factor; IMR environment

Propagation model	α	Applicability
High power IMR Low power IMR	0,284 0,277	Transparent IMR
Pedestrian A Vehicular A	0,838 0,506	Non-transparent IMR

For information, in absence of IMR, i.e. satellite signal only, the calculated orthogonality factor is as follows:

Table B.2: Orthogonality factor; Satellite environment (no IMR)

Propagation model	α
ITU A LOS	0,991
ITU A NLOS	0,951
ITU B LOS	0,989
ITU B NLOS	0,909
ITU C LOS	0,921
ITU C NLOS	0,473

B.4.3 Impact on system capacity

Loss of orthogonality due to propagation multi-paths has an impact on system capacity due to interference generated between channelization codes of a given carrier (parallel MBMS services) at UE antenna connector.

Assuming:

- all the downlink services are allocated the same data rate;
- all the connections require the same Eb/Nt (same channel propagation environment);
- all the connections are allocated the same power (same path loss conditions);
- a traffic activity factor of 1 (data service).

The downlink capacity for a large number of MBMS services can be approximated by:

$$Capacity_{DL}(kbps) = \frac{3840}{E_b/N_t} * \frac{1-c}{(1-\alpha+i)}$$

In case of a limited number of MBMS services, the number of users is given by:

$$N = (1-c)\left(\frac{1}{1-\alpha+i}\frac{W/R}{(Eb/N0)_{th}}\right) + (1-c)\left(\frac{1-\alpha}{1-\alpha+i}\right) - (1-c)\left(\frac{1}{1-\alpha+i}\left(\frac{Pn.Ll}{Puser}\right)\right)$$

where:

- c: is the fraction of power allocated to common channels (usually 10-20%);
- α: is the orthogonality factor;
- i: is the ratio of inter-cell to intra-cell interference;
- Pn: is the thermal noise (negligible to be compared to i in mobile environment).

B.5 3GPP User Equipment Capabilities

B.5.1 Rake Receiver

3GPP UE implements a Rake receiver which combines received signals for 2 types of diversity: multi-path diversity and macro-diversity.

B.5.2 Multi-path combining: multi-path diversity

Rake receiver combines all the paths at the chip level. The term Maximum Ratio Combining (MRC) is usually used.

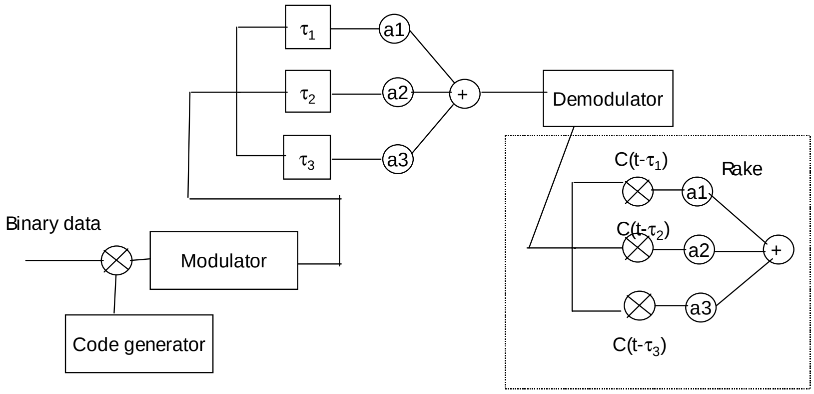


Figure B.4: Maximum Ratio Combining (MRC)

3GPP UE Rake receiver window length is designed to fit maximum delay according to tap propagation channels specified by 3GPP, i.e. 20 µs, which means latest guaranteed processed multi-path has a maximum delay of 20 µs for 3G commercial products.

B.5.2.1 Multi-code combining: macro-diversity

Multi-code combining at UE can be implemented either with:

- MRC: Rake receiver applies a distinct scrambling code to the taps at the chip level;
- Log Likelihood Ratio Combining (LLR) before the turbo decoder at symbol level as illustrated in figure B.5. This can be interpreted as implementing several Rake receiver windows in parallel.

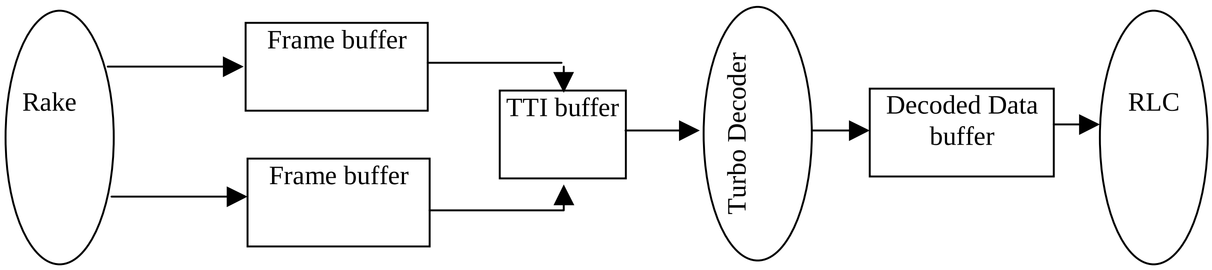


Figure B.5: Log Likelihood Ratio Combining (LLR)

B.5.3 Capabilities for MBMS (current status: Release 6)

3GPP is currently standardizing User Equipment (UE) and radio infrastructure capabilities for MBMS.

B.5.3.1 S-CCPCH Combining

A given MBMS data content may be delivered by a group of cells: each FACH of each cell (thus on a distinct scrambling code) transported over the cell specific scrambling code, carries the same data content.

In order to optimise MBMS radio resource allocation (transmission power), 3GPP introduced the capability for a UE to combine several FACHs from up to 3 cells, i.e. up to 3 distinct scrambling codes for FACH combining.

Because FACH is a common channel (shared by all the users under cell coverage), there is no way to adjust timing at UE reception and to guarantee multiple signals arrive within the UE 20 µs Rake receiver window. Thus 3GPP specifies UE capabilities for FACH combining from multiple cells, i.e. an extension of macro-diversity capability to S-CCPCH.

Several multi-scrambling codes combining methods were discussed at 3GPP:

- Selective combining: selection of the radio link is performed on a transport block basis at the RLC (layer 2), based on CRC results and sequence numbers, as illustrated in figure B.6;
- Soft combining: Log Likelihood Ratio (LLR) or Maximum Ratio Combining (MRC).

Up to now, only Soft Combining has been agreed by 3GPP to be a mandatory UE functionality for Release-6 MBMS. Selective combining is still under discussion.

So far, concerning soft combining methods, LLR is to be implemented. MRC has been discarded for it is considered impact on UE implementation cost is too grave.

When S-CCPCHs are soft combined, all S-CCPCHs shall contain identical bits in their data fields, although the TFCI fields of S-CCPCH in different clusters may be different. This major topic points out that combining is done at Rake receiver output.

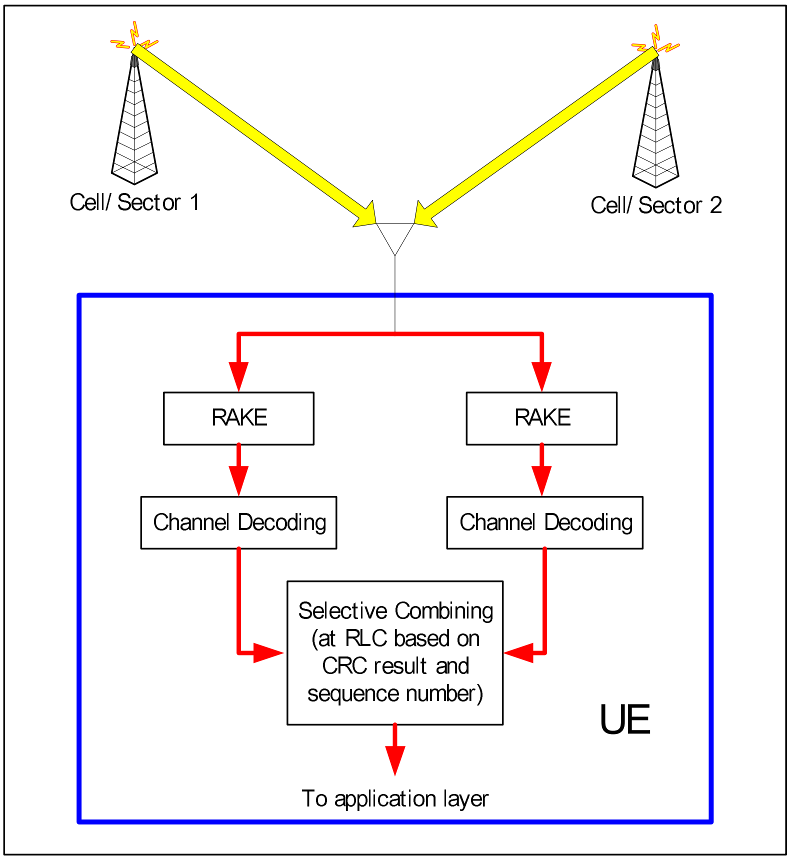


Figure B.6: Selective Combining

B.5.3.2 Synchronisation constraints

3GPP specifies maximum delays for multiple S-CCPCH combining, i.e. latest arrival at UE receiver as 1 TTI + 1 slot for both soft (and selective combining: to be confirmed) methods.

These values are to be compared to multi-path combining for which UE reception window is limited to 77 chips.

B.6 Intermediate Module Repeater (IMR)

Several types of repetitions could envisaged:

- Same frequency, different scrambling code: exploit UE MBMS soft/selective combining capabilities;

- Same frequency, same scrambling code (transparent IMR), artificial multi-paths: exploit UE multi-path combining capabilities (MRC Rake Receiver);
- Different frequency: full orthogonality, exploit UE reselection capabilities.

Each type of IMR has a distinct impact on either UE or infrastructure equipment, which means implementation over-cost at UE and/or infrastructure side.

B.6.1 Transparent IMR

IMRs re-amplify the signal received from the satellite, eventually after frequency conversion depending on the IMR feeding frequency band.

The satellite signal is repeated with the same scrambling code. This has an important impact on propagation channel: IMRs introduce artificial multi-paths. The result is an increase of loss of scrambling codes orthogonality at the receiver antenna connector (see clause B.4.2).

Moreover, the 3GPP UE Rake receiver window length limitation (latest multi-path delay $\leq$ 20 µs) drives to the following constraints:

- IMRs deployment is constrained by synchronisation issues (relatively to satellite signal), and IMR coverage is limited due to UE Rake receiver limitation, or
- For larger IMR coverage areas and/or relaxed deployment synchronisation constraints, UE Rake receiver window is to be enlarged. This means use of 3GPP standardised UE chipset is not anymore possible. Furthermore, adaptation cost may act as a brake on the economy of scales (due to memory increase caused by larger number of chips to be stored internally to the chipset).

This solution should be reserved to geographical areas where large IMR coverage is not required.

B.6.2 Regenerative IMR (non-transparent IMR)

The satellite signal is repeated with a different scrambling code, one scrambling code per IMR.

This solution allows to take benefit of the complete set of MBMS specific features introduced in Release6 (selective/soft combining, protocol features, etc.) and relaxes IMR synchronisation deployment constraints. It also allows to increase IMR coverage thus decreasing the number of IMRs to deploy.

IMR implementation may be based on 3GPP Node B, in which case it implements the complete physical layer. RNC at SDMB Hub manages related protocols (MBMS signalling, etc.).

This solution should be used in geographical areas where large IMR coverage is required.

B.7 Performance requirements and system capacity

B.7.1 Test environment

Performance requirements and system capacity are presented for 2 types of IMRs:

- Transparent IMR: IMRs repeat satellite signal with the same scrambling code, propagation channels extracted from [F] = Low power IMR (based on Pedestrian A) and High power IMR (based on vehicular A);
- Non-transparent IMR: each IMR is allocated a distinct scrambling code.

NOTE: For non-transparent IMRs, simulations were run with a path loss difference between IMR ref. and IMR 1 in the range 0 to 11 dB.

Propagation channels for transparent IMRs were calculated at a point where "nearest" adjacent IMR (e.g. IMR1) contribution is -3,7 dB. In order to get comparative data, tables hereafter, which summarise demodulation performances, contain the required Rx Eb/Nt for a path loss difference between IMR ref and IMR 1 set to -3,7 dB for the non-transparent IMRs.

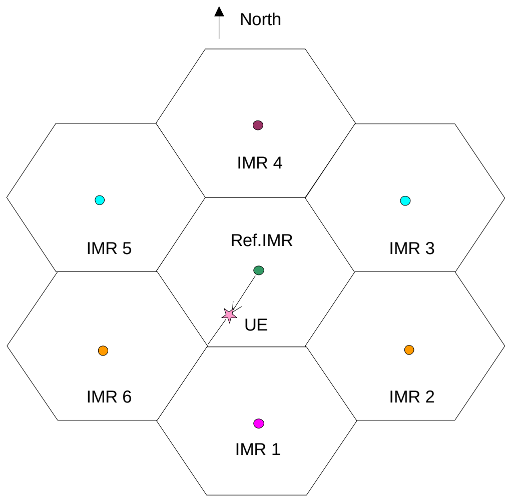


Figure B.7: IMR cellular layout

Capacity per carrier is also given for information. Capacity is presented as fractions of codes in order to highlight system limits.

- For non-transparent IMRs, the ratio of inter-cell to intra-cell interference has been calculated as -2,75 dB in pedestrian A environment and -2,96 dB in vehicular A environment (IMR ref and IMR1 are combined, satellite and all other IMRs act as inter-cell interference).

- For transparent IMRs, there is no inter-cell interference since the set of IMRs acts as a whole unique cell.

The total number of fingers of the Rake receiver was limited to 6. Performances capacity per carrier when the number of fingers of the Rake receiver would be extended to 12 is given for comparison in annex D. Note that for UE implementation cost reasons an assumption of 12 fingers may not be realistic.

The downlink capacity has been calculated assuming 10% of the maximum transmission power allocated to common channels.

The detailed simulation parameters for demodulation performance requirements were set as depicted in the table B.3:

Table B.3: Simulation parameters for S-CCPCH demodulation performance requirements

Parameter name	Value
Nb UE Rx antenna	1
Carrier frequency	2.2 GHz
UE Speed	3 - 50 km/h
AWGN Noise	ON
Fast fading	ON
Data rate (FACH)	16, 32, 64 or 128 kbps
Wanted BLER	~1%
Minimum number of slots simulated	50 000
Slot format	6, 8, 10,12
Interleaving depth	2, 4 or 8
Channel coding	Turbo
Nb DTX bits	0
Nb transport channels per physical channel	1
Nb CRC bits	16
Power offset L1 control/Data bits	0 dB
CPICH Ec/Ior	-10 dB
P-CCPCH Ec/Ior	-12 dB
SCH Ec/Ior (Primary + secondary)	-12 dB
Channel estimation Path searcher Path amplitude estimation	 Ideal Based on CPICH
Nb of cells in the UE active set	1: transparent IMR 2: soft combining of 2 cells
Path loss difference between cell 1 and cell 2 at UE receiver	From 0 to -11 dB by step of 1 dB. Note: significant only if Nb cells = 2
Propagation channel transparent IMRs	Low and high power IMRs
Propagation channel non-transparent IMRs	Pedestrian A, Vehicular A
Rake receiver: Nb of fingers	≤ 6

B.7.2 Data service 16 kbps

Required Rx Eb/Nt for a BLER of 1% is:

Table B.4: Rx Eb/Nt - 16 kbps

Data rate	16 kbps		Eb/Nt			S-CCPCH_Ec/Ior		
Speed	**IMR Type**	**Channel**	**20 ms**	**40 ms**	**80 ms**	**20 ms**	**40 ms**	**80 ms**
3 km/h	Transparent IMR	Low Power High Power	14 dB 14,2 dB	13,4 dB 13,6 dB	12,1 dB 12,4 dB	-10,2 dB -10,2 dB	-10,9 dB -10,8 dB	-12,1 dB -12 dB
	Non-transparent IMR	Pedestrian A Vehicular A	12,6 dB 10,5 dB	11,5 dB 9,7 dB	9,9 dB 8,5 dB	-8,4 dB -9,5 dB	-9,5 dB -10,3 dB	-11,2 dB -11,4 dB
50 km/h	Transparent IMR	Low Power High Power	10.9 dB 11 dB	10 dB 10.1 dB	9,5 dB 9,6 dB	-13,4 dB -13,4 dB	-14,2 dB -14,3 dB	-14,8 dB -14,8 dB
	Non-transparent IMR	Pedestrian A Vehicular A	7,7 dB 7,2 dB	6,5 dB 6,3 dB	5,8 dB 5,9 dB	-13,4 dB -12,8 dB	-14,5 dB -13,6 dB	-15,2 dB -14,1 dB

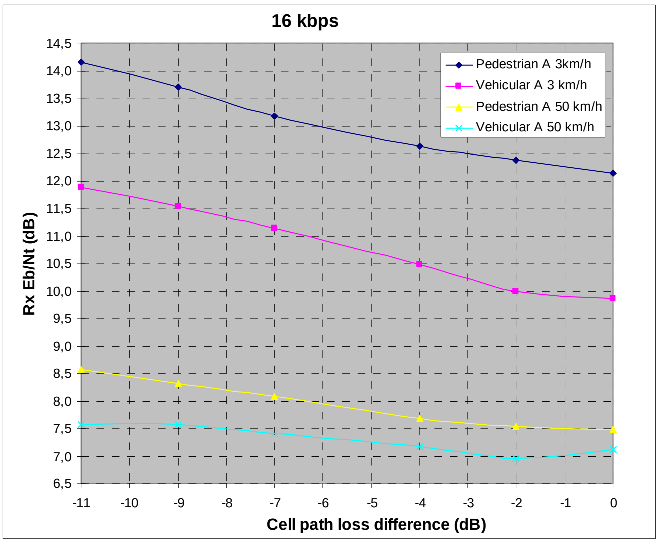


Figure B.8: Rx Eb/Nt = f(cell path loss difference); 16 kbps; TTI = 20 ms

Table B.5: Capacity per carrier 16 kbps

Data rate	16 kbps		Capacity per carrier (kbps)			Nb. of codes		
Speed	**IMR Type**	**Channel**	**20 ms**	**40 ms**	**80 ms**	**20 ms**	**40 ms**	**80 ms**
3 km/h	Transparent IMR	Low Power	203,15	235,04	305,79	12,70	14,69	19,11
		High Power	197,19	226,41	290,02	12,32	14,15	18,13
	Non-transparent IMR	Pedestrian A	275,08	352,54	517,45	17,19	22,03	32,34
		Vehicular A	317,22	376,79	491,66	19,83	23,55	30,73
50 km/h	Transparent IMR	Low Power	407,21	491,64	556,34	25,45	30,73	34,77
		High Power	400,71	481,35	542,80	25,04	30,08	33,93
	Non-transparent IMR	Pedestrian A	852,44	1115,07	1303,62	53,28	69,69	81,48
		Vehicular A	671,33	808,94	902,81	41,96	50,56	56,43

The increase of capacity per carrier when non-transparent IMRs are used, to be compared to the use of transparent IMRs, is summarized hereafter:

Table B.6: System capacity improvement with non-transparent IMRs; 16 kbps

Data rate	16 kbps	% capacity increase		
Speed	**Environment**	**20 ms**	**40 ms**	**80 ms**
Pedestrian A vs low power IMR	3 km/h	135%	150%	169%
	50 km/h	209%	227%	234%
Vehicular A vs High power IMR	3 km/h	161%	166%	170%
	50 km/h	168%	168%	166%

B.7.3 Data service 32 kbps

Required Rx Eb/Nt for a BLER of 1% is:

Table B.7: Rx Eb/Nt - 32 kbps

Data rate	32 kbps		Eb/Nt			S-CCPCH_Ec/Ior		
Speed	**IMR Type**	**Channel**	**20 ms**	**40 ms**	**80 ms**	**20 ms**	**40 ms**	**80 ms**
3 km/h	Transparent IMR	Low Power	14,3 dB	13,8 dB	12,5 dB	-6,9 dB	-7,4 dB	-8,7 dB
		High Power	14,6 dB	13,9 dB	12,7 dB	-6,8 dB	-7,5 dB	-8,7 dB
	Non-transparent IMR	Pedestrian A	12,9 dB	11,6 dB	10,1 dB	-5,2 dB	-6,4 dB	-7,9 dB
		Vehicular A	10,7 dB	9,8 dB	8,9 dB	-6,3 dB	-7,1 dB	-8,1 dB
50 km/h	Transparent IMR	Low Power	11 dB	10,1 dB	9,6 dB	-10,2 dB	-11,1 dB	-11,6 dB
		High Power	11,1 dB	10.3 dB	9,8 dB	-10,3 dB	-11,1 dB	-11,6 dB
	Non-transparent IMR	Pedestrian A	7,8 dB	6,7 dB	6 dB	-10,3 dB	-11,4 dB	-12,1 dB
		Vehicular A	7,2 dB	6.3 dB	6 dB	-9,8 dB	-10,7 dB	-11 dB

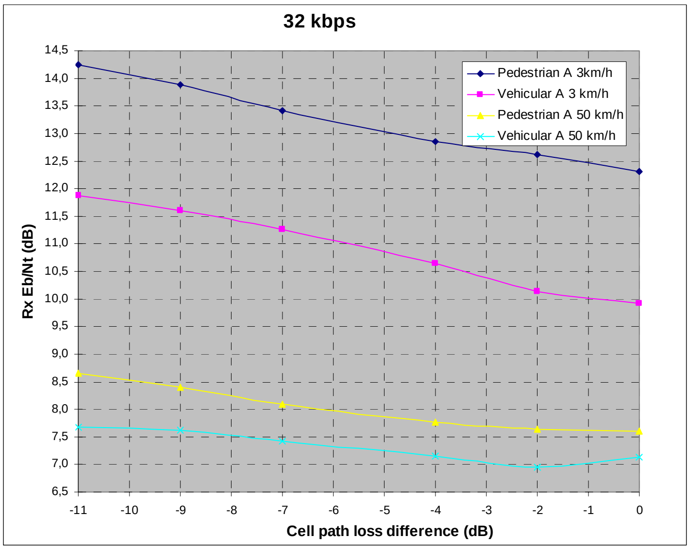


Figure B.9: Rx Eb/Nt = f(cell path loss difference); 32 kbps; TTI = 20 ms

Table B.8: Capacity per carrier 32 kbps

Data rate	32 kbps		Capacity per carrier (kbps)			Nb. of codes		
Speed	**IMR Type**	**Channel**	**20 ms**	**40 ms**	**80 ms**	**20 ms**	**40 ms**	**80 ms**
3 km/h	Transparent IMR	Low Power	204,91	226,76	295,47	6,40	7,09	9,23
		High Power	197,48	224,17	286,29	6,17	7,01	8,95
	Non-transparent IMR	Pedestrian A	265,08	351,58	489,44	8,28	10,99	15,29
		Vehicular A	311,79	372,54	460,68	9,74	11,64	14,40
50 km/h	Transparent IMR	Low Power	408,70	491,69	553,91	12,77	15,37	17,31
		High Power	405,49	479,53	535,40	12,67	14,99	16,73
	Non-transparent IMR	Pedestrian A	840,50	1078,32	1265,94	26,27	33,70	39,56
		Vehicular A	680,30	823,91	923,77	21,26	25,75	28,87

The increase of capacity per carrier when non-transparent IMRs are used, to be compared to the use of transparent IMRs, is summarised hereafter:

Table B.9: System capacity improvement with non-transparent IMRs 32 kbps

Data rate	32 kbps	% capacity increase		
Speed	**Environment**	**20 ms**	**40 ms**	**80 ms**
Pedestrian A vs low power IMR	3 km/h	129%	155%	166%
		206%	219%	229%
Vehicular A vs High power IMR	50 km/h	158%	166%	161%
		168%	172%	173%

B.7.4 Data service 64 kbps

Required Rx Eb/Nt for a BLER of 1% is:

Table B.10: Rx Eb/Nt 64 kbps

Data rate	64 kbps		Eb/Nt			S-CCPCH_Ec/Ior		
Speed	**IMR Type**	**Channel**	**20 ms**	**40 ms**	**80 ms**	**20 ms**	**40 ms**	**80 ms**
3 km/h	Transparent IMR	Low Power	14,4 dB	13,8 dB	12,4 dB	-3,8 dB	-4,4 dB	-4,9 dB
		High Power	14,8 dB	14,1 dB	12,9 dB	-3,6 dB	-4,3 dB	-5,5 dB
	Non-transparent IMR	Pedestrian A	12,5 dB	11,4 dB	7,9 dB	-2,5 dB	-3,6 dB	-6,3 dB
		Vehicular A	10,4 dB	9,7 dB	8,7 dB	-3,6 dB	-4,3 dB	-5,3 dB
50 km/h	Transparent IMR	Low Power	10,8 dB	10 dB	9,6 dB	-7,4 dB	-8,2 dB	-8,6 dB
		High Power	10,8 dB	10,1 dB	9,9 dB	-7,6 dB	-8,3 dB	-8,5 dB
	Non-transparent IMR	Pedestrian A	7,3 dB	6,3 dB	5,8 dB	-7,7 dB	-8,7 dB	-9,2 dB
		Vehicular A	6,7 dB	6,1 dB	5,9 dB	-7,2 dB	-7.9 dB	-8,1 dB

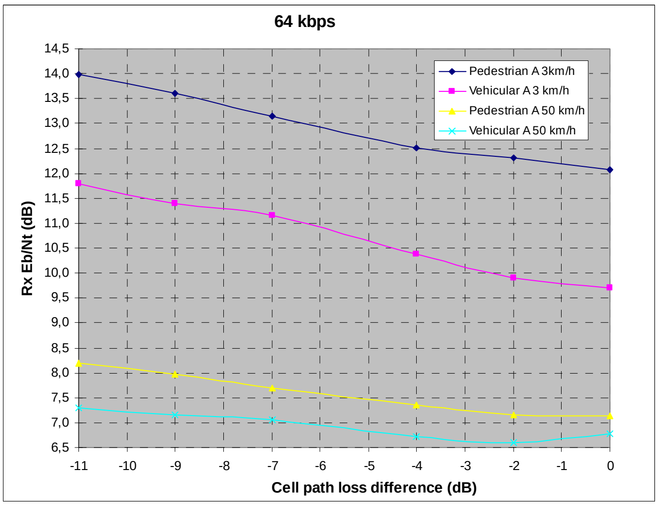


Figure B.10: Rx Eb/Nt = f(cell path loss difference) 64 kbps; TTI = 20 ms

Table B.11: Capacity per carrier - 64 kbps

Data rate	64 kbps		Capacity per carrier (kbps)			Nb. of codes		
Speed	**IMR Type**	**Channel**	**20 ms**	**40 ms**	**80 ms**	**20 ms**	**40 ms**	**80 ms**
3 km/h	Transparent IMR	Low Power	232,38	255,47	331,06	3,63	3,99	5,17
		High Power	215,89	244,00	303,89	3,37	3,81	4,75
	Non-transparent IMR	Pedestrian A	292,97	371,45	828,25	4,58	5,80	12,94
		Vehicular A	345,57	403,14	498,41	5,40	6,30	7,79
50 km/h	Transparent IMR	Low Power	459,05	539,02	581,21	7,17	8,42	9,08
		High Power	456,66	527,32	555,08	7,14	8,24	8,67
	Non-transparent IMR	Pedestrian A	931,82	1172,39	1319,59	14,56	18,32	20,62
		Vehicular A	763,43	882,20	922,58	11,93	13,78	14,42

The increase of capacity per carrier when non-transparent IMRs are used, to be compared to the use of transparent IMRs, is summarised hereafter:

Table B.12: System capacity improvement with non-transparent IMRs; 64 kbps

Data rate	64 kbps	% capacity increase		
Speed	**Environment**	**20 ms**	**40 ms**	**80 ms**
Pedestrian A vs low power IMR	3 km/h	126%	145%	250%
		203%	218%	227%
Vehicular A vs High power IMR	50 km/h	160%	165%	164%
		167%	167%	166%

B.7.5 Data service 128 kbps

Required Rx Eb/Nt for a BLER of 1% is:

Table B.13: Rx Eb/Nt - 128 kbps

Data rate	128 kbps		Eb/Nt			S-CCPCH_Ec/Ior		
Speed	**IMR Type**	**Channel**	**20 ms**	**40 ms**	**80 ms**	**20 ms**	**40 ms**	**80 ms**
3 km/h	Transparent IMR	Low Power	15,5 dB	15,1 dB	13.6 dB	0.3 dB	-0.1 dB	-1.6 dB
		High Power	15,8 dB	15,4 dB	13.7 dB	0.4 dB	0 dB	-1.7 dB
	Non-transparent IMR	Pedestrian A	12,5 dB	11,4 dB	9.9 dB	0.5 dB	-0.6 dB	-2.1 dB
		Vehicular A	10,4 dB	9,7 dB	8.7 dB	-0.6 dB	-1.3 dB	-2.3 dB
50 km/h	Transparent IMR	Low Power	10,9 dB	10,3 dB	9.8 dB	-4.3 dB	-4.9 dB	-5.4 dB
		High Power	11,1 dB	10,5 dB	10.1 dB	-4.3 dB	-4.9 dB	-5.3 dB
	Non-transparent IMR	Pedestrian A	7,2 dB	6,4 dB	5.7 dB	-4.8 dB	-5.7 dB	-6.3 dB
		Vehicular A	6,6 dB	9,7 dB	5.8 dB	-4.3 dB	-1.3 dB	-5.1 dB

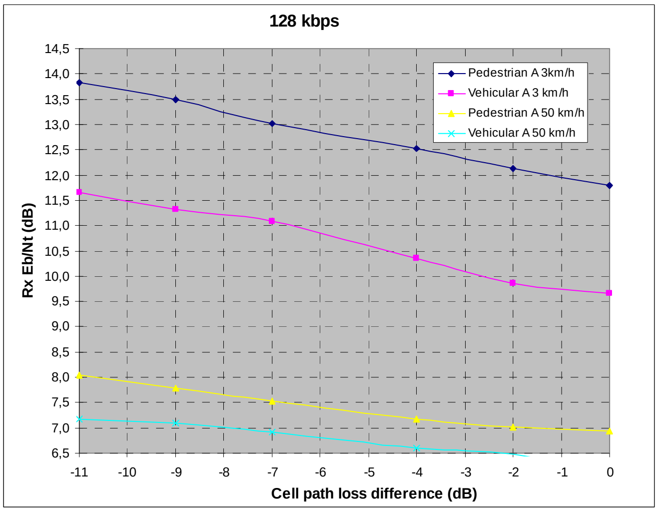


Figure B.11: Rx Eb/Nt = f(cell path loss difference) 128 kbps; TTI = 20 ms

Table B.14: Capacity per carrier: 128 kbps

Data rate	128 kbps		Capacity per carrier (kbps)			Nb. of codes		
Speed	**IMR Type**	**Channel**	**20 ms**	**40 ms**	**80 ms**	**20 ms**	**40 ms**	**80 ms**
3 km/h	Transparent IMR	Low Power	249,01	263,34	323,35	1,95	2,06	2,53
		High Power	241,60	255,53	320,01	1,89	2,00	2,50
	Non-transparent IMR	Pedestrian A	305,52	386,30	531,75	2,39	3,02	4,15
		Vehicular A	375,14	428,89	528,10	2,93	3,35	4,13
50 km/h	Transparent IMR	Low Power	505,93	562,03	617,61	3,95	4,39	4,83
		High Power	489,36	547,60	590,81	3,82	4,28	4,62
	Non-transparent IMR	Pedestrian A	981,26	1180,41	1358,24	7,67	9,22	10,61
		Vehicular A	813,83	962,31	967,28	6,36	7,52	7,56

The increase of capacity per carrier when non-transparent IMRs are used, to be compared to the use of transparent IMRs, is summarised hereafter:

Table B.15: System capacity improvement with non-transparent IMRs; 128 kbps

Data rate	128 kbps	% capacity increase		
Speed	**Environment**	**20 ms**	**40 ms**	**80 ms**
Pedestrian A vs low power IMR	3 km/h	123%	147%	164%
		194%	210%	220%
Vehicular A vs High power IMR	50 km/h	155%	168%	165%
		166%	176%	164%

B.8 Conclusion

Use of combining technique, i.e. non-transparent IMRs, when the total number of Rake receiver fingers is limited to 6, gives also the benefit of important capacity increase, particularly for high data rate:

- In pedestrian environment (versus low power transparent IMR): by 45-110% at 3 km/h and 115-145% at 50 km/h;
- In vehicular environment (versus low power transparent IMR): by 70-150% at 3 km/h and 70-100% at 50 km/h.

NOTE: these results come from situations when combining is performed with only 2 cells. Capacity gain should be even more improved when UE combines 3 non-transparent IMR cells.

These result are to be considered keeping in mind that non-transparent IMRs allow to decrease IMR deployment constraints such as synchronisation, to increase IMR coverage and does not require 3GPP UE modem modification.

Finally, performance and capacity can be compared with the case of UE Rake receiver implementing up to 12 fingers. Results for a TTI of 20 ms are shown in annex D. Note that for UE implementation cost reasons an assumption of 12 fingers may not be realistic. Nevertheless, operating UEs implementing 12 fingers would bring a capacity increase, more especially for transparent IMRs:

- Non-transparent IMR: from 10 to 29%;
- Transparent IMR: up to 400%.

Additionally, extending interleaving depth from 2 to 8 gives the benefit of capacity increase by ~35 % for UE's speed at 50 km/h (~50% in pedestrian environment) and 50-55 % at 3 km/h (~80-87% in pedestrian environment).

It is thus proposed to insert demodulation performance requirements for MBMS soft combining in the S-UMTS Technical Specification "MBMS Performance over the radio interface".

Annex C: Propagation Channels

C.1 ITU Satellite channels

Table C.1: Channel model A (10% delay spread values)

Tap number	Relative tap delay value (ns)	Tap amplitude distribution	Parameter of amplitude distribution (dB)	Average amplitude with respect to free space propagation	Rice factor (dB)	Doppler spectrum
1	0	LOS: Rice NLOS: Rayleigh	10 log c 10 log P_m	0,0 -7,3	10 -	Rice Classic
2	100	Rayleigh	10 log P_m	-23,6	-	Classic
3	180	Rayleigh	10 log P_m	-28,1	-	Classic

Table C.2: Channel model B (50% delay spread values)

Tap number	Relative tap delay value (ns)	Tap amplitude distribution	Parameter of amplitude distribution(dB)	Average amplitude with respect to free space propagation	Rice factor (dB)	Doppler spectrum
1	0	LOS: Rice NLOS: Rayleigh	10 log c 10 log P_m	0,0 -9,5	7 -	Rice Classic
2	100	Rayleigh	10 log P_m	-24,1	-	Classic
3	250	Rayleigh	10 log P_m	-25,1	-	Classic

Table C.3: Channel model C (90% delay spread values)

Tap number	Relative tap delay value (ns)	Tap amplitude distribution	Parameter of amplitude distribution(dB)	Average amplitude with respect to free space propagation	Rice factor (dB)	Doppler spectrum
1	0	LOS: Rice NLOS: Rayleigh	10 log c 10 log P_m	0.0 -12,1	3 -	Rice Classic
2	60	Rayleigh	10 log P_m	-17,0	-	Classic
3	100	Rayleigh	10 log P_m	-18,3	-	Classic
4	130	Rayleigh	10 log P_m	-19,1	-	Classic
5	250	Rayleigh	10 log P_m	-22,1	-	Classic

C.2 Combined satellite and IMR channels

Combined satellite and IMR channels are extracted from Satin project. They are applicable to transparent IMRs.

Table C.4 Low power IMR (Based on Pedestrian A)

Sat		Ref. IMR		IMR1		IMR2	
Relative Delay (µs)	Avg. Power (dB)	Relative Delay (µs)	Avg. Power (dB)	Relative Delay (µs)	Avg. Power (dB)	Relative Delay (µs)	Avg. Power (dB)
0,00	-3,8	1,99	0,0	0,32	-3,7	2,44	-13,2
		2,30	-1,0	0,63	-4,7	2,75	-14,2
		2,70	-9,0	1,03	-12,7	3,15	-22,2
		3,08	-10,0	1,41	-13,7	3,53	-23,2
		3,72	-15,0	2,05	-18,7	4,17	-28,2
		4,50	-20,0	2,83	-23,7	4,95	-33,2
IMR3		**IMR4**		**IMR5**		**IMR6**	
Relative Delay (µs)	**Avg. Power (dB)**	**Relative Delay (µs)**	**Avg. Power (dB)**	**Relative Delay (µs)**	**Avg. Power (dB)**	**Relative Delay (µs)**	**Avg. Power (dB)**
5,18	-17,5	6,16	-17,5	4,41	-13,2	1,30	-3,7
5,49	-18,5	6,47	-18,5	4,72	-14,2	1,61	-4,7
5,89	-26,5	6,87	-26,5	5,12	-22,2	2,01	-12,7
6,27	-27,5	7,25	-27,5	5,50	-23,2	2,39	-13,7
6,91	-32,5	7,89	-32,5	6,14	-28,2	3,03	-18,7
7,69	-37,5	8,67	-37,5	6,92	-33,2	3,81	-23,7

Table C.5: High power IMR (Based on Vehicular A)

Sat		Ref IMR		IMR1		IMR2	
Relative Delay (µs)	Avg. Power (dB)	Relative Delay (µs)	Avg. Power (dB)	Relative Delay (µs)	Avg. Power (dB)	Relative Delay (µs)	Avg. Power (dB)
0,00	-6,5	9,96	0,0	1,58	-3,7	1,58	-3,7
		10,27	-1,0	1,89	-4,7	1,89	-4,7
		10,67	-9,0	2,29	-12,7	2,29	-12,7
		11,05	-10,0	2,67	-13,7	2,67	-13,7
		11,69	-15,0	3,31	-18,7	3,31	-18,7
		12,47	-20,0	4,09	-23,7	4,09	-23,7
IMR3		**IMR4**		**IMR5**		**IMR6**	
Relative Delay (µs)	**Avg. Power (dB)**	**Relative Delay (µs)**	**Avg. Power (dB)**	**Relative Delay (µs)**	**Avg. Power (dB)**	**Relative Delay (µs)**	**Avg. Power (dB)**
25,91	-17,5	30,83	-17,5	22,04	-13,2	6,50	25,91
26,22	-18,5	31,14	-18,5	22,35	-14,2	6,81	26,22
26,62	-26,5	31,54	-26,5	22,75	-22,2	7,21	26,62
27,00	-27,5	31,92	-27,5	23,13	-23,2	7,59	27,00
27,64	-32,5	32,56	-32,5	23,77	-28,2	8,23	27,64
28,42	-37,5	33,34	-37,5	24,55	-33,2	9,01	28,42

C.3 Terrestrial ITU channels

Terrestrial ITU channels are applicable to non-transparent IMRs.

Table C.6: Pedestrian A

Tap	Channel A		Doppler Spectrum
	Rel. Delay (nsec)	Avg. Power (dB)	
1	0	0	CLASSIC
2	110	-9,7	CLASSIC
3	190	-19,2	CLASSIC
4	410	-22,8	CLASSIC
5	-	-	CLASSIC
6	-	-	CLASSIC

Table C.7: Vehicular A

Tap	Channel A		Doppler Spectrum
	Rel. Delay (nsec)	Avg. Power (dB)	
1	0	0,0	CLASSIC
2	310	-1,0	CLASSIC
3	710	-9,0	CLASSIC
4	1090	-10,0	CLASSIC
5	1730	-15,0	CLASSIC
6	2510	-20,0	CLASSIC

Annex D: Performance with increased number of Rake fingers

Performance when the total number of fingers of the Rake receiver is not limited to 6 but extended to 12, for Transparent IMR (High and low power) and Vehicular A is given hereafter for information. Also are given the performance gain and the radio capacity per carrier to be compared to a Rake receiver limited to 6 fingers.

All of these results apply to a TTI equal to 20 ms. Note that for transparent IMRs, 3 IMRs are combined (most power IMRs) while for Vehicular A simulations were run with combination of only 2 IMRs.

Table D.1: Performances and radio capacity; Nb_fingers=12; 16 kbps

Data rate	16 kbps		SCCPCH_ Ec/Ior	Gain/ 6 fingers	Capacity per carrier	Capa. improv./ 6 fingers
Speed	IMR Type	Channel				
3 km/h	Transparent IMR	Low Power	-10,4 dB	5,2 dB	701	245%
		High Power	-11 dB	5,6 dB	621	215%
	Non trans IMR	Vehicular A	-10,4 dB	0,9 dB	388	22%
50 km/h	Transparent IMR	Low Power	-12,6 dB	4,1 dB	1104	171%
		High Power	-13 dB	4,4 dB	1010	152%
	Non trans IMR	Vehicular A	-13,4 dB	0,6 dB	764	14%

Table D.2: Performances and radio capacity; Nb_fingers=12; 32 kbps

Data rate	32 kbps		SCCPCH_ Ec/Ior	Gain/ 6 fingers	Capacity per carrier	Capa. Improv./ 6 fingers
Speed	IMR Type	Channel				
3 km/h	Transparent IMR	Low Power	-7,88 dB	5,85 dB	706	245%
		High Power	-7,41 dB	5,54 dB	633	221%
	Non trans IMR	Vehicular A	-7,35 dB	1,04 dB	392	26%
50 km/h	Transparent IMR	Low Power	-9,57 dB	4,21 dB	1108	171%
		High Power	-9,90 dB	4,53 dB	1023	152%
	Non trans IMR	Vehicular A	-10,31 dB	0,50 dB	761	12%

Table D.3: Performances and radio capacity; Nb_fingers=12; 64 kbps

Data rate	64 kbps		SCCPCH_ Ec/Ior	Gain/ 6 fingers	Capacity per carrier	Capa. improv./ 6 fingers
Speed	IMR Type	Channel				
3 km/h	Transparent IMR	Low Power	-5,09 dB	6,11 dB	771	232%
		High Power	-4,59 dB	6,02 dB	690	220%
	Non trans IMR	Vehicular A	-4,59 dB	1,01 dB	429	24%
50 km/h	Transparent IMR	Low Power	-7,25 dB	4,65 dB	1228	168%
		High Power	-6,89 dB	4,30 dB	1131	148%
	Non trans IMR	Vehicular A	-7,66 dB	0,43 dB	841	10%

Table D.4: Performances and radio capacity; Nb_fingers=12; 128 kbps

Data rate	128 kbps		SCCPCH_ Ec/Ior	Gain/ 6 fingers	Capacity per carrier	Capa. improv./ 6 fingers
Speed	IMR Type	Channel				
3 km/h	Transparent IMR	Low Power	-2,06 dB	7,24 dB	824	231%
		High Power	-1,53 dB	6,94 dB	740	206%
	Non trans IMR	Vehicular A	-1,70 dB	1,12 dB	468	25%
50 km/h	Transparent IMR	Low Power	-4,36 dB	4,89 dB	1320	161%
		High Power	-3,99 dB	4,69 dB	1216	148%
	Non trans IMR	Vehicular A	-4,80 dB	0,46 dB	898	10%

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