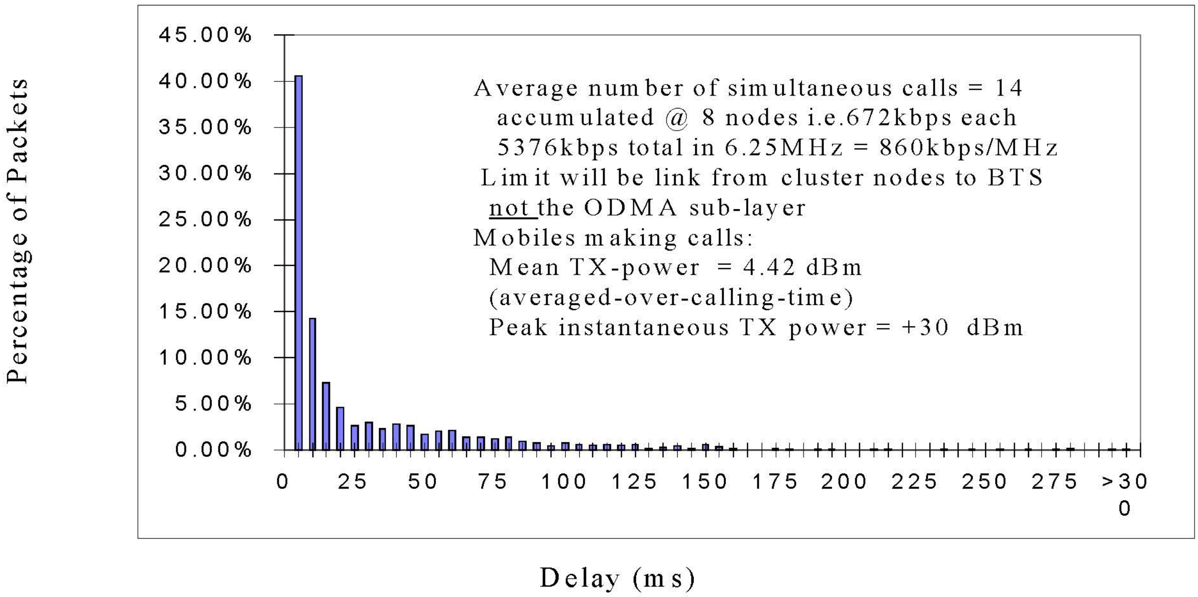


*Figure 20 Packet Delay Distribution for Manhattan 3x3 Block LCD 384kbps Capacity*

# 6. WCDMA SUPPORT FOR RELAYING

This section presents the findings from joint Alpha/Epsilon feasibility study which considered how the radio sub-blocks within the WCDMA mobile could support relaying.

WCDMA communication in ODMA mode implies MS-to-MS communication. This, in turn, implies MS reception and transmission on the same frequency band, i.e. TDD operation.

TDD is already included as a key feature of the WCDMA proposal of the concept group Alpha and only a very limited amount of additional features have to be added to a WCDMA terminal in order to support relaying as will be discussed below.

For MS-to-MS communication, the transmit and receive spreading/modulation schemes of the mobile stations should obviously be the same. This is currently not the case for the Alpha concept where the mobile station uses IQ-multiplex of the DPCCH and DPDCH followed by dual-channel QPSK modulation. For the downlink, i.e. the signal received by the mobile station uses time multiplex of the DPCCH and DPDCH followed by ordinary QPSK modulation. It is recommended that, for the WCDMA/ODMA mode, MS-to-MS communication will use the downlink scheme of the Alpha concept. Such an approach will have an only marginal impact on the complexity of the mobile-station transmitter as QPSK can be seen as a special case of dual-channel QPSK.

In ODMA mode, a mobile terminal will initiate transmission with a random-access burst, identical to the ordinary random-access burst of the Alpha RACH. The target MS will detect this random-access burst in a similar way as the BS detects the RACH. This may indicate the need to add a relatively complex RACH detector in the ODMA terminal. However, the main component of the RACH detector (see figure X) is a matched filter identical to the matched filter used for cell search. Even the filter parameters can be the same. The main difference is the addition of the symbol-sampled preamble filter in the case of a RACH detector. However, this is very similar to the slot-wise accumulation of matched-filter outputs in the case of the cell-search. It may even be argued of the preamble of the RACH is actually needed for WCDMA/ODMA communication. The preamble is included in the Alpha concept to support the reception of multiple RACH simultaneously. It is not yet fully clear of that functionality will be needed in the ODMA access-burst detector.

Consequently, only marginal hardware modifications need to be added to a WCDMA/TDD terminal in order to support ODMA communication

The following block diagrams show a breakdown of the WCDMA receiver building blocks which must be considered in order to support relaying.

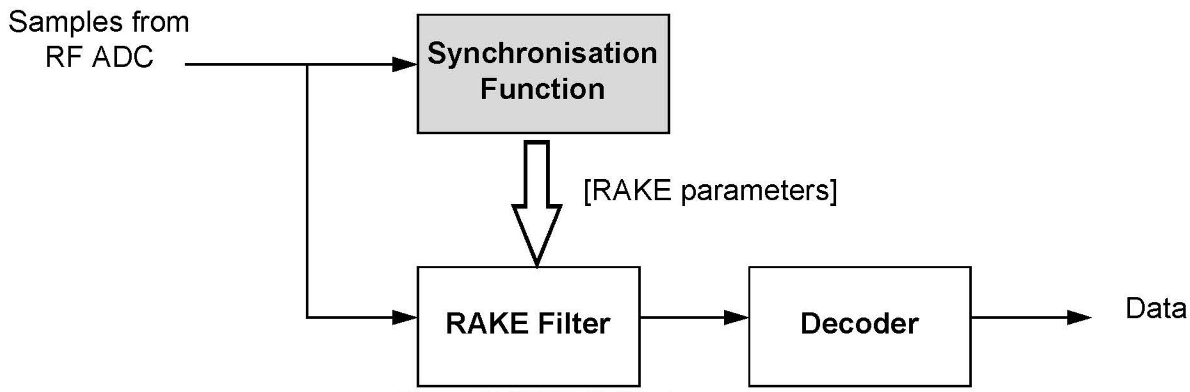


*Figure 21 WCDMA Receiver*

Figure 21 shows a block diagram of a typical WCDMA receiver. The synchronisation function must be modified as it is assumed that chip and symbol synchronisation cannot be obtained from BTS broadcasts when in ODMA mode (although some basic system time synch is possible from toggling to WCDMA mode). This block is expanded in Figure 22

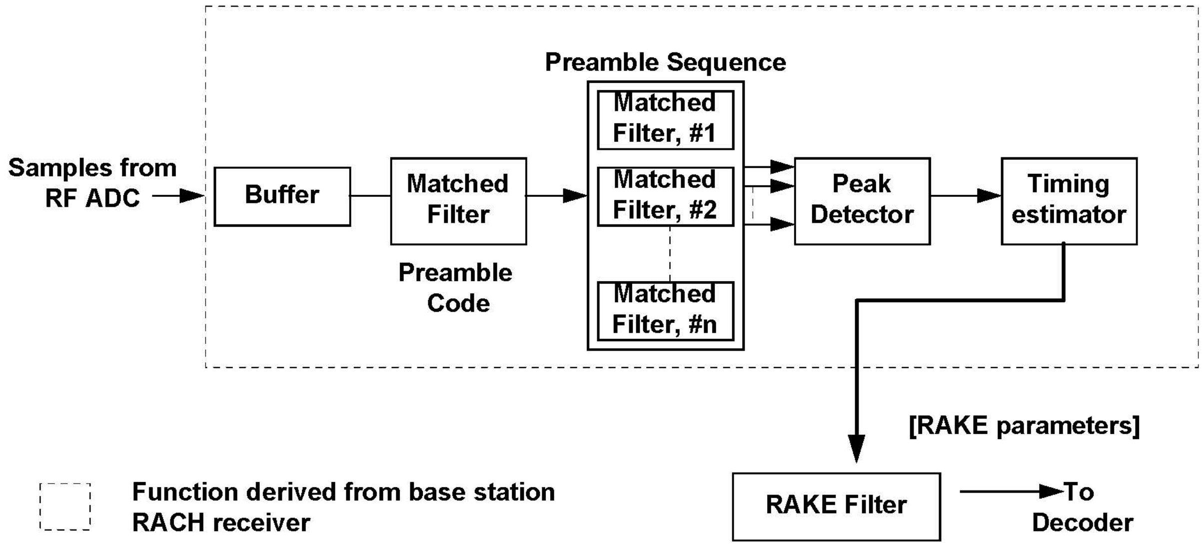


*Figure 22 Synchronisation Function*

The dotted box indicates functionality derived from the BTS design for dealing with RACH transmissions. RACH transmissions are asynchronous and must be tolerant to collisions and Near Far effects (meets ODMA criteria). Basically matched filters are used to synchronise on a transmission by transmission basis .

The first matched filters looks for a PN sequence common to all preambles. The filter hardware already exists within a WCDMA MS in the form of a BTS searcher. The matched filters for finding particular preambles would need to be added but these are much simpler as they are clocked at a slow rate. The remaining blocks of Figure 22 are also present in the MS and the matched filters are shown below in Figure 23

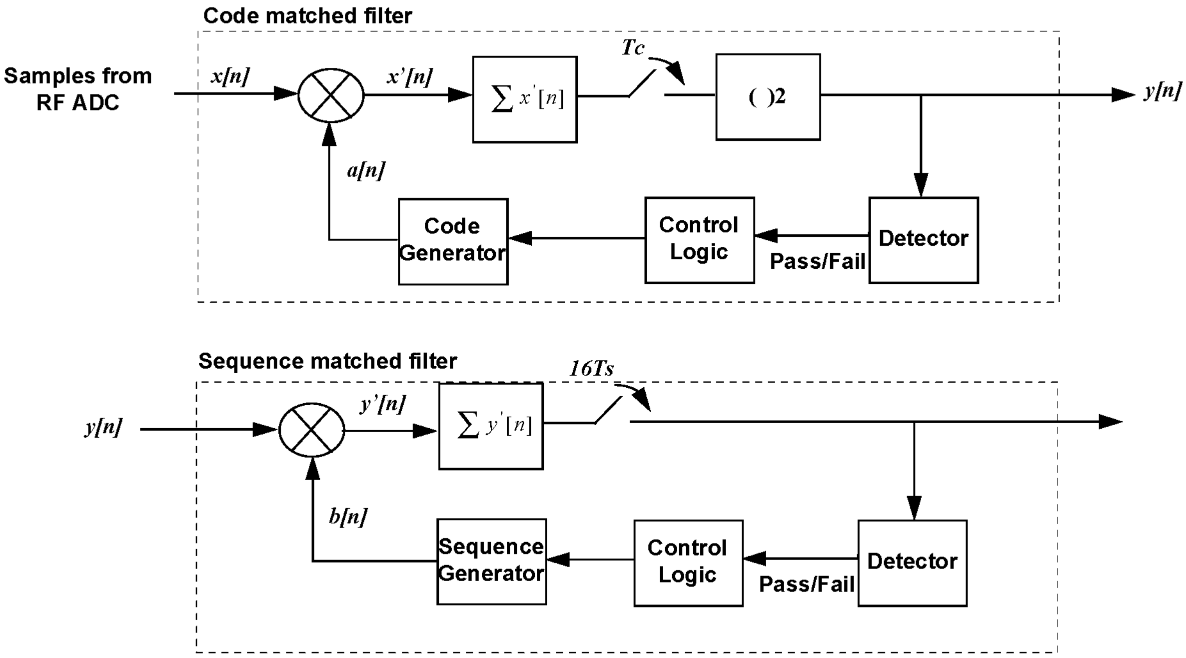


*Figure 23 Receiver Matched Filters*

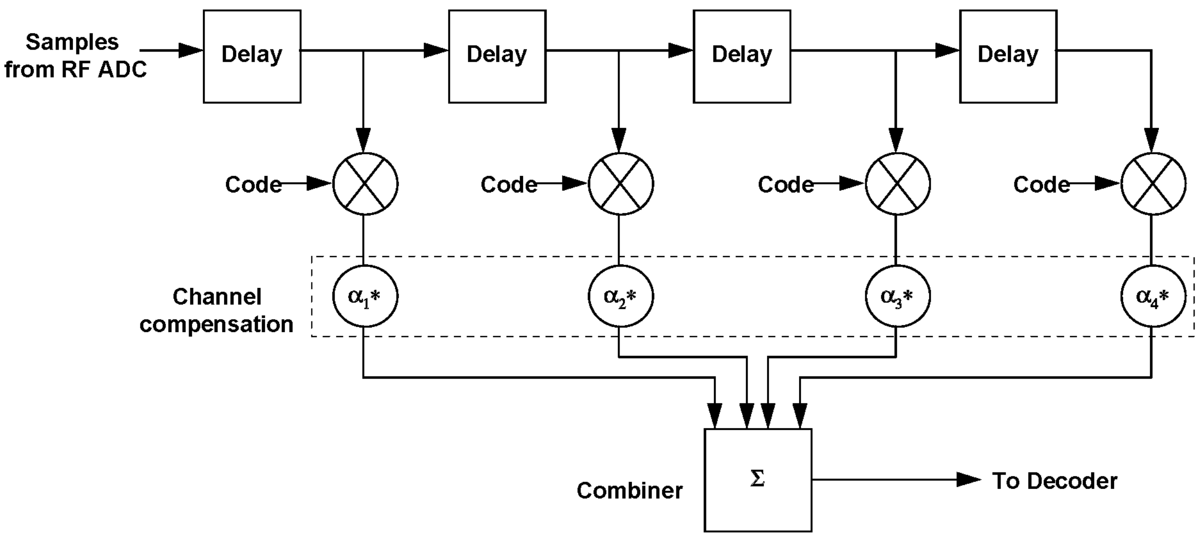


*Figure 24 WCDMA Rake Receiver*

A typical WCDMA rake receiver is shown in Figure 24 and whilst it requires no significant modification it must be used with care in a relaying receiver. For example if there are many preamble codes then it is unlikely that MSs will attempt to re-use the same one within a local area and so the rake fingers will have multipath delayed versions of the desired signal which can be combined using MRC. Alternatively if there are few preambles, perhaps just one then there will be interfering transmissions on the same code. The fingers of the Rake receiver may have signals from a number of sources rather than multipath from just one so MRC would not be appropriate. In this case it would be better to select a single path. This would be justified for many relaying cases when short low delay spread paths are used.

## 6.1 Benefits of WCDMA to ODMA implementation

For the ODMA communication with basically random transmission of packets, it is very difficult to rely on interference avoiding techniques (interference occurs on different time-slots and carriers for different packets). Consequently it is important to use a transmission scheme that is as robust to interference as possible. In this way, parallel packet transmissions, also at relatively nearby links will not cause fatal collisions. WCDMA gives such a high robustness towards interference and does thus provides a good basis for ODMA:

## 6.2 Cost/complexity

As stated earlier the initial feasibility study suggests that only marginal hardware modifications need to be added to a WCDMA/TDD terminal in order to support ODMA communication

# 7. CALL SET-UP PROCEDURES FOR ODMA IN A WCDMA CELL.

Within a WCDMA cell that supports ODMA we will consider that all mobiles have the same basic functionality i.e.; they can time multiplex between WCDMA FDD mode and ODMA TDD mode. ODMA traffic will be carried in a separate unpaired spectrum band but the last relay hop to the BTS will use WCDMA/FDD.

Within the cell there are several MS roles e.g.;

1) Mobile originator/terminator

2) Active relay

3) Sleeping relay

4) ODMA/WCDMA gateway (last hop)

All the mobiles can receive broadcast information from the BTS and thereby establish basic system timing synchronism.

ODMA requires a background probing activity to determine the location of near neighbours which may act as future relays. If this is allowed to occur at any time the MSs must RX continuously which may reduce battery life. To avoid this, a low duty cycle probing window is used i.e. the sleeping MSs wake up periodically to send and receive probes (e.g. every minute) and then go back to sleep. The window could be of the order of 0.5 seconds long.

The BTS has the capability to send a wakeup page to all the MSs via the WCDMA/FDD cell.

A Sleeping MS that is then paged awake will stay active whilst it can detect local ODMA transmissions. If it has not participated in such communication for a timeout period it will fall asleep. Similarly it may decide to sleep after a long period of activity

When a MO wishes to start a call it makes a conventional RACH access to the WCDMA/FDD BTS. A conventional authentication/call setup will take place but during the negotiation of resource it will be decided to use ODMA mode. Firstly the BTS will send a broadcast wakeup page to the MS relays. The BTS will then ask the MO to send a message to it via ODMA relaying which it then acknowledges. The initial route for these messages will be based on knowledge acquired from the background probing. The transmissions will be monitored by relays not directly involved in the link. These relays then determine connectivity routes between the MO and BTS and are available to make further transmissions more optimum and reliable. Other mobiles will fall asleep using the page-awake rules. A similar procedure is used for MT calls.

## 7.1 ODMA/WCDMA Gateway - Last Hop to BTS

The last MS in the relay chain will have direct connectivity to the BTS over a short high rate link. The MS will require 2 buffers i.e.; to fill from ODMA and empty via WCDMA and vice versa. For example in the case of significant DL traffic the buffer will be filled by a WCDMA call and at a defined threshold the MS will switch to ODMA mode until the buffer is emptied. Similarly for an UL case ODMA will fill the buffer until a threshold is reached after which a WCDMA call empties the buffer into the BTS. If an ODMA relay is not available as in WCDMA mode traffic is either backed up toward the source or an alternative last hop MS is chosen.

# 8. BENEFITS OF ODMA TO WCDMA W.R.T. HIGH LEVEL REQUIREMENTS

The potential benefits of ODMA as a WCDMA enhancement are listed below with respect to the UTRA high level requirements.

| **Key Requirements** | **Description** |
|---|---|
| | **Bearer capabilities** |
| **Maximum User Bit Rates** | The UTRA should support a range of maximum user bit rates that depend upon a users current environment as follows:<br>Rural Outdoor[1]: at least 144 kbit/s (goal to achieve 384 kbit/s), maximum speed: 500 km/h<br>Suburban Outdoor[2]: at least 384 kbps (goal to achieve 512 kbit/s), maximum speed: 120 km/h<br>Indoor/Low range outdoor[3]: at least 2Mbps, maximum speed: 10 km/h<br>It is desirable that the definition of UTRA should allow evolution to higher bit rates.<br>*The maximum user bit rate for packet services in the given environments are determined by the assumptions on channel models and maximum range. If relaying is supported then these assumptions change as communication proceeds via a number of relay hops which are normally low range, low mobility and often LOS. Therefore relaying enables high rate transmissions in all environments.*<br>*Where high rate transmission was already possible, relaying will lower the required transmitted power.* |

[1] The specified bit rate will be available throughout the operator's service area, with the possibility of large cells

[2] The specified bit rate will be available with complete coverage of a suburban or urban area, using microcells or smaller macrocells

[3] The specified bit rate will be available indoors and locallised coverage outdoors.

| | |
|---|---|
| **Flexibility** | Negotiation of bearer service attributes (bearer type, bit rate, delay, BER, up/down link symmetry, protection including none or unequal protection), parallel bearer services (service mix), real-time / non-real-time communication modes, adaptation of bearer service bit rate<br>Circuit and packet oriented bearers<br>Supports scheduling (and pre-emption) of bearers (including control bearers) according to priority<br>Adaptivity of link to quality, traffic and network load, and radio conditions (in order to optimise the link in different environments).<br>Wide range of bit rates should be supported with sufficient granularity<br>Variable bit rate real time capabilities should be provided.<br>Bearer services appropriate for speech shall be provided.<br>*WCDMA is a flexible and adaptive air interface technology and relaying further enhances these capabilities for packet services. Using ODMA you not only have the opportunity to perform optimum link adaption but you may have a number of different links (relay paths) from which to select the best and thereby bypass heavy shadowing effects. ODMA adds link diversity to WCDMA.*<br>*When a MS uses a relay it is effectively replacing it's own transmission limitations with that of a neighbour who is better situated or more able to communicate. For example a low power handportable MS could relay to a vehicle in order to exploit the more powerful transmitter and better antenna to reach a distant BTS or satellite. In these examples the single hop relay means that low delay speech can be supported as well as data services. For the satellite case this gives the option of indoor coverage using a simple UMTS handset..* |
| **Handover** | Provide seamless ( to user ) handover between cells of one operator.<br>The UTRA should not prevent seamless HO between different operators or access networks.<br>Efficient handover between UMTS and 2nd generation systems, e.g. GSM, should be possible. |

| | **OPERATIONAL REQUIREMENTS** |
|---|---|
| **Compatibility with services provided by present Core Transport Networks** | ATM bearer services<br>GSM services<br>IP (internet protocol) based services<br>B/N-ISDN services |
| **Radio Access Network Planning** | If radio resource planning is required, automatic planning shall be supported. |
| **Public network operators** | It shall be possible to guarantee pre-determined levels of quality-of-service and quality to public UMTS network operators, in the presence of other authorised UMTS users. |

| | |
|---|---|
| **Private and residential operators** | The radio access scheme should be suitable for low cost applications where range, mobility and user speed may be limited.<br>Multiple unsynchronised systems should be able to successfully coexist in the same environment.<br>It should be possible to install basestations without co-ordination.<br>Frequency planning should not be needed.<br>*Private and residential systems are particularly appropriate for relaying and ODMA.*<br>*As ODMA relays do not own dedicated radio resource but share it in an asynchronous fashion with neighbouring nodes they are tolerant to spectrum sharing.*<br>*For example ODMA could be used in the same spectrum band within adjacent buildings. This is particularly true as relaying avoids higher power transmissions at the building edge - in fact the highest average transmission powers can be concentrated at the centre of the cell/building. ODMA can be considered as a wireless distributed antenna.*<br>*In private companies another option is possible. A MS can exchange signalling with a BTS for call set-up authentication/encryption/user profiles etc. but the data content of the intracompany calls could be transmitted direct MS-MS or via MS relays. The capacity of such a system may be great and can be considered analogous to having a great many BTSs within a given area. In this scenario the delay of relayed calls is also very low and would be appropriate for speech as well as higher rate data services.*<br>*In a residential property there maybe a requirement for the UMTS MS to act as a low power cordless phone. The ODMA protocol has a probing mechanism to determine its near neighbours so that if the cordless BTS supported ODMA a MS could detect that it was "at home". The MS could then communicate directly to the BTS using the ODMA band without affecting the Operator's paired spectrum. The direct link would be low delay and suitable for speech as well as higher rate data services.* |

| | **EFFICIENT SPECTRUM USAGE** |
|---|---|
| **Spectrum efficiency** | High spectrum efficiency for typical mixtures of different bearer services.<br>Spectrum efficiency at least as good as GSM for low bit rate speech.<br>*Spectrum efficiency is limited by intercell and intracell interference. Intercell interference can be caused by a mobile on the edge of a cell transmitting at high power to reach it's BTS. The transmissions will interfere with neighbouring cells whose coverage will have been planned to ensure their are no gaps between them. WCDMA counteracts intercell interference by using SHO but this is not used for packet services.*<br>*Another approach is possible with relaying. Plan the WCDMA cells so that there are coverage gaps for high rate packet services (not necessarily speech). A BTS can then only serve MSs at short range which implies low transmission power and a long distance to the neighbour BTS. Serving these few MSs will be spectrally efficient as there would be simple low loss radio channels, with very little intercell interference. The coverage gaps would be filled in by ODMA relaying which would route traffic to and from the close range or optimally placed MSs.*<br>*This technique may also be applicable to reduce intercell interference at country borders.*<br>*Another factor which affects spectral efficiency is the protection methods to ensure reliable transmission in difficult environments which may have high error rates and long delay spreads. WCDMA provides rugged protection methods for these environments but because relaying shortens and simplifies the communication paths less protection may be required.*<br>*[It should be noted that within a cell area an ODMA sublayer using subscriber relay would re-use the radio resources many times as each re-transmission is of such low power that they will only effect a small percentage of the cell area.]* |
| **Variable Asymmetry of Total Band Usage** | variable division of radio resource between uplink and down link resources from a common pool (NB: This division could be in either frequency, time, or code domains)<br>*Relaying will be supported in a TDD mode within a separate section of spectrum. Within this spectrum, complete asymmetry is supported with no requirement for a predefined UL/DL split of any kind.. However as relaying is part of a hybrid WCDMA solution the relay spectrum may logically be considered as adding to the WCDMA DL or UL thereby considerably increasing support for variable asymmetry when dealing with packet services.* |
| **Spectrum Utilisation** | Allow multiple operators to use the band allocated to UMTS without co-ordination.[4]<br>It should be possible to operate the UTRA in any suitable frequency band that becomes available such as first & second generation system's bands |

[4] NOTE: the feasibility of spectrum sharing requires further study.

| | |
|---|---|
| **Coverage / Capacity** | The system should be flexible to support a variety of initial coverage/capacity configurations and facilitate coverage/capacity evolution<br>Flexible use of various cell types and relations between cells (e.g. indoor cells, hierarchical cells) within a geographical area without undue waste of radio resources.<br>Ability to support cost effective coverage in rural areas<br>*A major feature of relaying is the prospect to extend service coverage either by extending high data rate services or by relaying from deadspots into coverage. It would be a means to limit the required number of BTS sites to achieve coverage whilst maintaining the customer perceived QoS. Relaying has potential may to combat intercell interference which would allow BTS equipment to achieve greater capacity.*<br>*If relaying is used to help initial rollout then it may be necessary to deploy Seeds (operator deployed-powered relaying mobiles). As the number of subscribers increase the Seeds will no longer be necessary .Ultimately more BTS resources will be added to cope with high capacity demands.* |
| | **Complexity/cost** |
| **Mobile Terminal viability** | Handportable and PCM-CIA card sized UMTS terminals should be viable in terms of size, weight, operating time, range, effective radiated power and cost.<br>*A WCDMA MS should readily support relaying as it already contains the required radio block functionality.* |
| **Network complexity and cost** | The development and equipment cost should be kept at a reasonable level, taking into account the cost of cell sites, the associated network connections , signalling load and traffic overhead (e.g. due to handovers).<br>*Relaying would make use of the equipment proposed for WCDMA and by extending the range of the high rate data services it would require less BTSs for a given coverage area.* |
| **Mobile station types** | It should be possible to provide a variety of mobile station types of varying complexity, cost and capabilities in order to satisfy the needs of different types of users.<br>*For a relay system to work well there must be as many relay nodes as possible. It is therefore a goal to support relaying in all mobiles - as it is believed that little extra cost or complexity is implied.*<br>*It is accepted that the lowest cost mobiles will have limited ability for relaying high rate packet services.* |
| | **Requirements from bodies outside SMG** |
| **Alignment with IMT 2000** | UTRA shall meet at least the technical requirements for submission as a candidate technology for IMT 2000 (FPLMTS)<br>*WCDMA meets these requirements but the development of relaying options could give the European solution an advantage over other world standards* |

| | |
|---|---|
| **Minimum bandwidth allocation** | It should be possible to deploy and operate a network in a limited bandwidth<br>*The relaying sub-layer requires a single separate spectrum band (unpaired) which is used throughout the network. The smallest allocation unit for WCDMA is one 5MHz carrier which can support fairly high data rates if intercell interference is controlled*<br>*The band maybe taken from an operator's own spectrum but there are advantages in having an additional default band, e.g. the UMTS spectrum allocated in each country to unlicensed use which can be used on a low power sharing basis.* |
| **Electro-Magnetic Compatibility (EMC)** | The peak and average power and envelope variations have to be such that the degree of interference caused to other equipment is not higher than in today's systems.<br>*The relaying system will strive to localise the effects of any transmission by minimising the transmitted power of a call.* |
| **RF Radiation Effects** | UMTS shall be operative at RF emission power levels which are in line with the recommendations related to electromagnetic radiation. |
| **Security** | The UMTS radio interface should be able to accommodate at least the same level of protection as the GSM radio interface does.<br>*A security review of ODMA has shown that the potential attacks are very similar to those for GSM. Providing GSM like authentication and end-to-end payload encryption are carried out then the level of protection is comparable.* |
| **Coexistence with other systems** | The UMTS Terrestrial Radio Access should be capable to co-exist with other systems within the same or neighbouring band depending on systems and regulations |
| | **Multimode implementation capabilities** |
| | It should be possible to implement dual mode UMTS/GSM terminals cost effectively. |

# 9. SUMMARY

The use of relaying will add interesting new functionality and flexibility to a WCDMA UTRA and every effort should be made to ensure it is included in the standard especially as initial investigations suggest that the required functionality has negligible impact on mobile terminal cost or complexity.

As discussed in section 6 the properties of WCDMA are particularly advantageous to the use of advanced relaying protocols such as ODMA.

The ODMA/WCDMA combination should be further investigated as simulation results obtained during the ETSI evaluation process have demonstrated the potential for significant coverage and capacity enhancements.

# 10. ASSOCIATED DOCUMENTS

List of associated documents currently available from the Epsilon Group;

| TD number | Title | Source |
|---|---|---|
| E-1/97 | Agenda & material for discussion | Chairman |
| E-2/97 | Mailing list & document handling | Secretary |
| E-2/97Rev1 | Mailing list & document handling | Secretary |
| E-3/97 | Radio Interface Structure | Chairman |
| E-4/97 | Report of the 1st ODMA Concept Group meeting | Secretary |
| E-5/97 | Outline of the Technical Discussion | Chairman |
| E-6/97 | Low-cost, low-power terminals for basic services | Motorola |
| E-7/97 | Concept Group ε - ODMA - Report | Chairman |
| E-8/97 | ODMA/CTDMA - Initial Discussions on Convergence | Vodafone Ltd<br>Swiss Telecom PTT |
| E-9/97 | Towards a Consistent Interpretation of ETR SMG-50402 | Vodafone Ltd |
| E-10/97 | Notes on the Simulation of ODMA | Vodafone Ltd |
| E-11/97 | Operator's Key Questions to the UTRA Concept Groups | T-Mobil, MMO, TIM, CSELT, FranceTelecom/CNET, Vodafone, Telia, BT, Telecom Finland, Swiss Telecom PTT, KPN, Cellnet, Omnitel |
| E-12/97 | Outline of Evaluation Activities for Concept e - ODMA | Chairman |
| E-12/97Rev1 | Outline of Evaluation Activities for Concept e - ODMA | Chairman |
| E-13/97 | Salbu Patent - "Adaptive Communication System" | Salbu |
| E-14/97 | Investigation into Average and Instantaneous BER Performance of a π/4 QPSK on UMTS Channels | LGI |
| E-15/97 | Average BER Performance on UMTS Channels with Paket Transmission considering π/4 QPSK and TCM8 PSK modulation | Kings College |

| | | |
|---|---|---|
| E-16/97 | Concept Group ε meeting report/presentation | Chairman |
| E-17/97 | Answers to Operator Interest Group Questions | Chairman |
| E-18/97 | WB-TDMA/CDMA/ODMA Feasibility Study | Siemens/Vodafone/Salbu |
| E-19/97 | Initial Results from ODMA Simulations | Vodafone |
| E-20/97 | ODMA - Opportunity Driven Multiple Access | Vodafone & Salbu |
| E-21/97 | Characteristics of Opportunity Driven Multiple Access | Vodafone & Salbu |
| E-22/97 | ODMA - System Gain from Fast Fading | Vodafone & Salbu |
| E-23/97 | Q&A Session Report | Chairman |
| E-24/97 | Questions to Concept Epsilon - ODMA | Chairman |
| E-25/97 | Concept Group ε Report (SMG2 UMTS Ad Hoc #4) | Chairman |
| E-26/97 | ODMA Annex to Alpha Evaluation Report | Chairman |
| E-27/97 | ODMA Annex to Delta Evaluation Report | Chairman |

# Annex B:

# Concept Group Beta β - Orthogonal Frequency Division Multiple Access (OFDMA)

**This report contained in this annex was prepared during the evaluation work of SMG2 as a possible basis for the UTRA standard. It is published on the understanding that the full details of the contents have not necessarily been reviewed by, or agreed by, ETSI SMG or SMG2.**

**ETSI SMG#24** **Tdoc SMG**
**894/97**
**Madrid, Spain**
**December 15th-19th, 1997**

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**Source** : **SMG2**

**Subject** : Summary of the concept description of the Beta concept

**Allocation** : Agenda Item **4.1**

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# 1. Introduction

This documents outlines the basic system characteristic of OFDMA which is proposed for UTRA selection. It describes the basic concept behind the OFDMA proposal and its advantages and featuers which is the most advanced of its kind present today.
The OFDMA supports the RTT structure which includes physical as well as netwrok protocol layers (Layer 1, 2, 3) and efficient Radio Resource Management mechanisms.
The OFDMA concept is unique in its approach to resolve the problem of interference averaging, combat multipath effect efficiently and increase capacity and spectral efficiency which are of a magnitude higher than any 2$^{nd}$ generation system available commercially today.
One of the main featuer of the proposed air-interface, OFDMA, is its flexibility in terms of operational matters, allocation of bandslot in a manner has not seen before, and also its service allocation flexitibilty (mix service in one cell).
It also provide the best guard band requirments of any system under study, of order of KHz rather than MHz. In OFDMA, the minimum guard band is 200 KHz.
The system structured in such a way which is backward compatible with the existing 2$^{nd}$ generation systems.
The implementation of low cost dual mode/band terminal is realistic.

# 2. Key technical characteristic of the basic system

The following table summarises the key technical parameters and characteristics of the OFDMA UTRA proposal.

| | |
|---|---|
| Multiple Access Scheme | SFH-TDMA and OFDM (BDMA) |
| Duplex Method | FDD (and TDD) |
| OFDM carrier spacing | 100kHz/24 = 4.17kHz |
| OFDM symbol duration | 240µs |
| Modulation time/Guard time | 278µs/38µs |
| Timeslot Length | 288µs |
| Bandslot Width (Minimum BW) | 100kHz (24 subcarriers) |
| Data frame length | 4.615ms (16 slot/frame) |
| Bandwidth | 100kHz, 200kHz, 400kHz, 800kHz, 1.6MHz (flexible) |
| Frequency Hopping | 1 (hop/burst) = 867 hop/s (no hopping option) |
| Channel Coding | Convolution coding, rate 1/3-2/3,<br>Optional outer RS coding (rate: 4/5) |
| Interleave | typical 18.46ms for speech |
| Subcarrier modulation scheme | Frequency Domain DQPSK, Frequency Domain D8PSK,<br>Coherent modulation schemes are supported |
| Bit rates | typical 11.6kB/s per timeslot/bandslot (coding=1/3) |
| Frequency Reuse | 1 (fractional load=30%), 3 (load=100%) |
| Maximum use bitrate | no limitation (depends on system BW) |
| Power Control | Open loop & closed loop |
| Power Control step, period | 1dB, 1.153ms/control |
| Frequency deployment step | 100kHz |
| Services | Connection oriented and packet oriented services are supported |
| Handover | Hard handover, Soft handover not required |
| GSM backwards compatibility | Time and frequency structure is compatible to GSM |

# 3. Performance Enhancing Features

The flexibility of the OFDM proposal (only the time and frequency grid structure has to be defined) allows the adoption of many performance enhancing features. Some of them are:

- Transmitter Diversity
  To increase decrease signal fluctuation by fast fading Tx antenna diversity is supported, a simmilar effect can be achieved by transmission of the same signal twice with a small delay from the same antenna (BS needs only single antenna).
- Adaptive Antennas
  The concept supports adaptive antennas (smat antennas) to support SDMA (spatial division multiple access) to increase range, coverage and capacity.
- Advanced Modulation/Coding Schemes
  New modulation schemes can be applied (adaptive modulation) on the subcarrier domain (actual C/I based). Improved coding schemes (e.g. Turbo coding) can also be used.
- Multi user detection/Interference cancellation
  Is supported in synchronous networks
- Dynamic Channel allocation
  Advance DCA scheme can be applied to avoid the interference and maximises the capacity.
- Bandwidth expansion
  Higher bandwidth allocation to support higher data rate beyond 2 Mb/s.

# 4. System Description

The OFDMA concept utilises OFDM modulation which has excellent performance in all multipath radio channels. A variable number of subcarriers is assigned to a user according to the required service. Additionally the number of timeslots is adjusted according to the required service. Variable bandwidth (frequency) and TDMA hopping pattern are supported, to achieve frequency, interference, and time diversity. The time and frequency structure is compatible to GSM.
FDD and TDD modes are supported.
The basic concept is depicted in Figure 1.

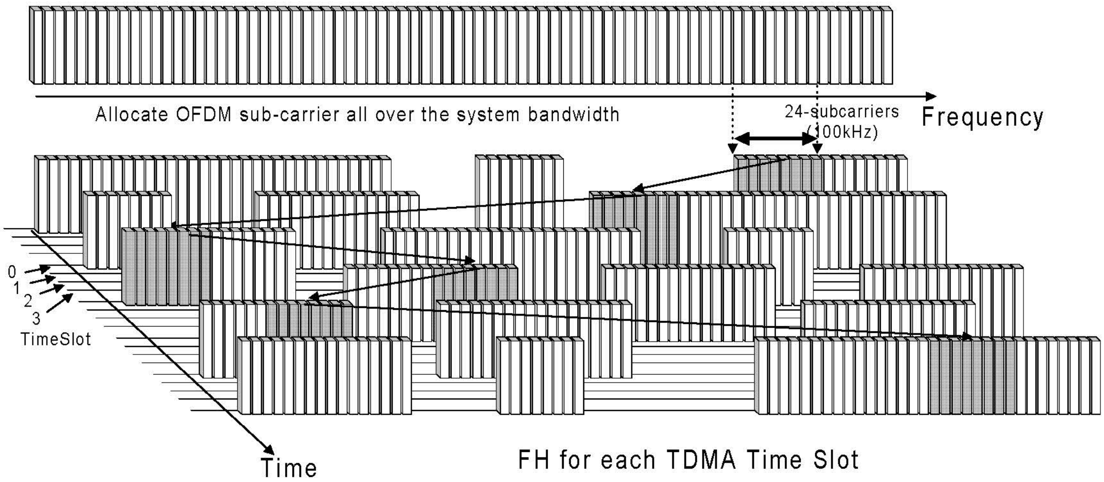


**Figure 1: OFDMA Outline (SFH-TDMA)**

The TDMA structure is aligned with GSM, one timeslot is 288.46µs (half of GSM timeslot). To support a wide variety of services flexible TDMA structures are supported in the FH pattern generator, the basic frame length is equivalent to the GSM frame length of 4.6ms.

Figure 2 shows the mapping of subcarriers into bandslots. One bandslots consist of 24 subcarriers (=100kHz) which is half of the GSM channel bandwidth.

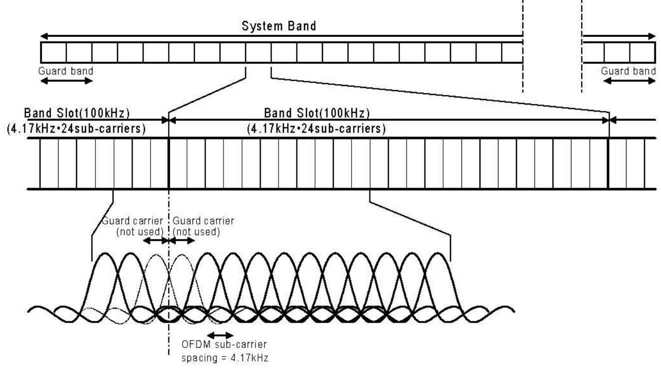


**Figure 2: OFMDA mapping of subcarriers**

Logical Channel are defined in the OFDMA concept:
Initial Aquisition Channel (IACH for initial time and frequency aquisition), Broadcast channel (BCCH) and Random Access Channel (RACH), Paging Channel (PCH).
Dedicated Control Channels (DCCH), Access Grant Channel (AGCH) and traffic channels are prepared.

Efficient quality based power control is achieved in the up- and downlink in order to minimise interference and maintain the link quality in the multipath environment.

A frequency reuse of 1 is supported which simplifies cell planning, the overall system shows soft capacity (allows capacity enhancement). Uncoordinated operation of basesations is supported.

The OFDM concept is optimised for efficient transmission of variable bitrates for conection oriented and packet oriented services.
The following diagram depicts the harmonised utilisation of the proposed (OFDMA) RTT basic resources for common operation in different environments.

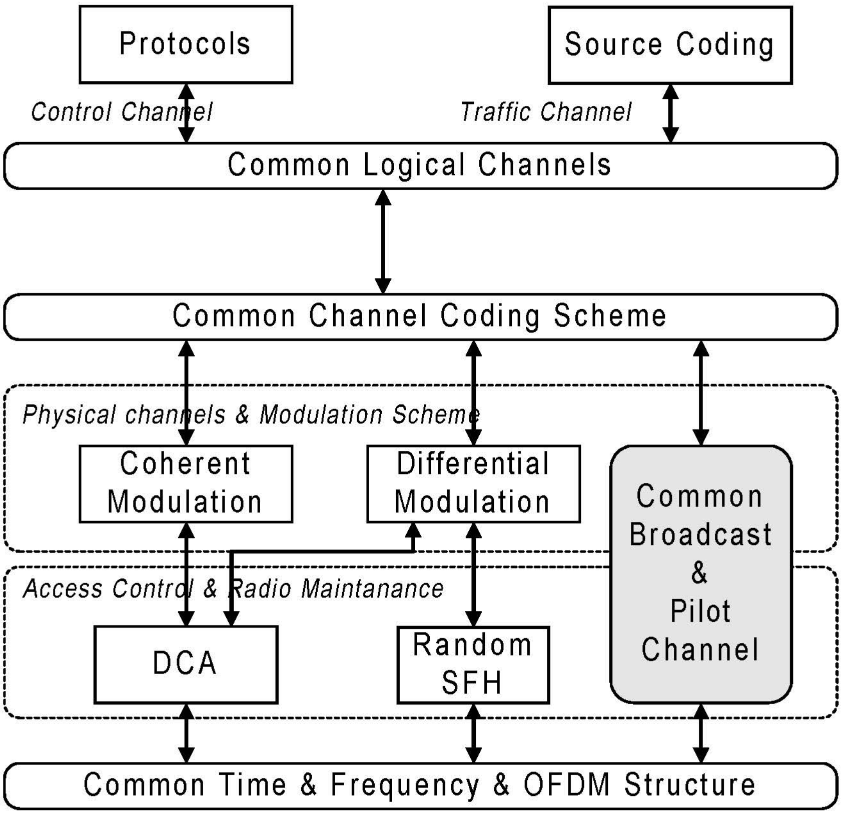


**Figure 3: Harmonised RTT platform**

# 5. Summary and main system features

The following summary shows the key advantages of the OFDMA UTRA proposal.

- Single core PHY layer minimising hardware costs with 2 software driven MAC options
- SFH TDMA based MAC for majority of UMTS services
- TDD DCA MAC for unpaired spectrum allocations, asymmetrical services & unlicensed usage
- Adaptive Modulation schemes for different channels
- Robustness against multi-path and Doppler spread
- Low computational overheads
- Simple low cost low-bit rate only terminals feasible
- Straightforward and efficient high bit rate support
- Small guard band requirements ~ 100 kHz
- High Spectral Efficiency achievable - 2 Mbits/s in 1.6 MHz feasible
- No frequency planning is required - effective re-use factor of ~1
- GSM Backwards Compatibility
- Minimum Bandwidth Requirements for system deployment only 1.6 MHz (or less) and deployment possible in steps of 100kHz
- Standard TDMA cellular planning and system enhancement techniques (smart antennas, hierarchical cell structures) can be supported
- Support of connection and packet oriented services
- Hard Handover, no soft handover required

**ETSI SMG#24**
**Madrid, Spain**
**December 15th-19th, 1997**

**Tdoc SMG 895/97**

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| | | |
|---|---|---|
| **Source** | **:** | SMG2 |
| **Subject** | **:** | Summary of the concept evaluation of the Beta concept |
| **Allocation** | **:** | Agenda Item **4.1 UTRA** |

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# 1. Introduction

This document describes evaluation summary the OFDMA concept based on the High Level Requirements for UTRA. Boxed text from ETR 04-01 has been included for reference.
This document does not outline the detail results, however, the full description of the system and results achieved can be found in the evaluation document.

# *2.* Maximum user bit rate

| |
|---|
| The UTRA should support a range of maximum user bit rates that depend upon a users current environment as follows:<br>Rural Outdoor: at least 144 kbit/s (goal to achieve 384 kbit/s), maximum speed: 500 km/h<br>Suburban Outdoor: at least 384 kbps (goal to achieve 512 kbit/s), maximum speed: 120 km/h<br>Indoor/Low range outdoor: at least 2Mbps, maximum speed: 10 km/h<br>It is desirable that the definition of UTRA should allow evolution to higher bit rates. |

- Rural Outdoor: 144kbps will be available throughout the operator's service area. The radio interface can tolerate the Doppler spread and rapidly changing channel characteristics associated with high speed vehicles (up to at least 1500 km/h).
- Suburban Outdoor: 384kbps rate will be available with complete coverage of a suburban or urban area
- Indoor/Low range outdoor: >2Mbps will be available indoors and over localised coverage outdoors

# 3. Flexibility

| |
|---|
| Negotiation of bearer service attributes (bearer type, bit rate, delay, BER, up/down link symmetry, protection including none or unequal protection),<br>parallel bearer services (service mix), real-time / non-real-time communication modes, adaptation of bearer service bit rate<br>Circuit switched and packet oriented bearers<br>Supports scheduling (and pre-emption) of bearers (including control bearers) according to priority<br>Adaptivity of link to quality, traffic and network load, and radio conditions (in order to optimise the link in different environments).<br>Wide range of bit rates should be supported with sufficient granularity<br>Variable bit rate real time capabilities should be provided.<br>Bearer services appropriate for speech shall be provided. |

The OFDMA concept can provide variety of bearer services with the necessary attributes. i.e. different connection modes, symmetry, communication configuration, information transfer rate, delay variation, maximum transfer delay, maximum bit error rate, error characteristics.

The OFDMA concept is best suited to flexible operation and support of different bearer services in different radio environments. The OFDMA uses enhancing features to dynamically maintain the quality of the connection under different propagation and interference conditions by adjusting transmission band slot and number of time slots allocated.
Bit rate granularity is achieved primarily by allocating different numbers of transmission slots, but this can be supplemented if necessary by adjusting channel coding rates.
Parallel bearers can be transmitted independently, or where appropriate by multiplexing together into a single channel.
Circuit switched and packet oriented services are supported efficiently by Real-Time and Non-Real-Time bearer concepts.
Variable rate data services are supported by dynamically changing the resources and their allocation.
Bearers optimised for speech are available.
The bearer service attributes can be configured as required on initiation of a service, and changed dynamically if required.

# 4. Minimum bearer capabilities

The following table shows the potential combinations for the most important characterisation attributes (based on ETR-04-01).

| | Real Time/Constant Delay | | Non Real Time/Variable Delay | |
|---|---|---|---|---|
| **Operating environment** | **Peak Bit Rate (note 6)** | **BER / Max Transfer Delay (note 1)** | **Peak Bit Rate** | **BER / Max Transfer Delay (note 2)** |
| **Rural outdoor (terminal speed up to 500 km/h)** | at least 144 kbit/s granularity 13kb/s (note 3) | delay 20 - 300 ms BER $10^{-3}$ - $10^{-7}$ | at least 144 kbit/s | BER = $10^{-5}$ to $10^{-8}$ Max Transfer Delay 150 ms or more |
| **Urban/ Suburban outdoor (Terminal speed up to 120 km/h)** | at least 384 kbit/s granularity 74kb/s (note 4) | delay 20 - 300 ms BER $10^{-3}$ - $10^{-7}$ | at least 384 kbit/s | BER = $10^{-5}$ to $10^{-8}$ Max Transfer Delay 150 ms or more |
| **Indoor/ Low range outdoor (Terminal speed up to 10 km/h)** | 2 Mbit/s granularity 150kb/s (note 5) | delay 20 - 300 ms BER $10^{-3}$ - $10^{-7}$ | 2 Mbit/s | BER = $10^{-5}$ to $10^{-8}$ Max Transfer Delay 150 ms or more |

Table 1: Minimum bearer capabilities for UMTS

Speech bearers are supported in all operating environments.

Note 1: The minimum achievable transmission delay is less than 20ms. For a given BER operation at lower C/I is possible by extending the interleaving depth. The detailed performance trade-offs between delay and BER (via choice of modulation, coding and interleaving) require further study.

Note 2: The delivery time for NRT/variable delay bearers depends on factors such as operating environment and traffic loading. Delivery times of the order of 150ms with BER in the stated range can be provided (using Type II soft combining ARQ).

Note 3: The indicated granularity is based on BOQAM with a single 1/64 slot allocation and 1/2 rate coding

Note 4: The indicated granularity is based on BOQAM with a single 1/16 slot allocation and 1/2 rate coding

Note 5: The indicated granularity is based on QOQAM with a single 1/16 slot allocation and 1/2 rate coding

Note 6: Finer granularity can be provided by variation of channel coding rate.

# 5. Service traffic parameters

The OFDMA supports 1-frequency reuse without the need for soft handover, which can support the use of UMTS in various environments with a range of traffic densities and a variety of traffic mixes in most economical manner.

# 6. Evolution and modularity

The OFDMA concept is service independent, and very flexible in resource management and allocation which is utilised in the implementation of UMTS in phases with enhancements for increasing functionality (for example making use of different modulation and coding technology).

With flexible resource allocation, the OFDMA concept is most suitable for the support of the requirements of an open modular architecture.

# 7. Handover

| |
|---|
| Provide seamless ( to user ) handover between cells of one operator.<br>The UTRA should not prevent seamless HO between different operators or access networks.<br>Efficient handover between UMTS and 2nd generation systems, e.g. GSM, should be possible. |

### 7.1. Overall handover requirements

Efficient seamless (mobile assisted) handovers can be provided in networks and between TDD and FDD systems.
The OFDMA supports Network handover, Mobile Assisted handover, Forward and MSC assisted handovers.
Handover to second generation systems can be supported by use of an idle frame allowing measurements of signal strengths from alternative base stations.

### 7.2. Handover requirements with respect to the radio operating environments

The OFDMA radio interface allows handovers within a network, between different environments and between networks run by different operators.

## 8. Operational requirements

### 8.1. Compatibility with services provided by present core networks

ATM bearer services
GSM services
IP (Internet Protocol) based services
ISDN services
Flexible RT and NRT bearers with a range of bit rates etc., allow current core network services to be supported.

### 8.2. Operating environments

OFDMA does not restrict the operational scenario for UMTS, in, for example, international operation across various radio operating environments, across multiple operators and across different regulatory regimes. Further, a range of different MS types (e.g. speech only, high bit rate data), and a variety of services with a range of bit rates are possible.

### 8.3. Support of multiple radio operating environments

OFDMA can support the requirements of all the specified radio operating environments.

### 8.4. Radio Access network planning

| |
|---|
| If radio resource planning is required automatic planning shall be supported |

With the flexible resource allocation, the network planning is not as sensitive as in case of GSM.
DCA can be used to re-configure the use of assigned frequency blocks in response to changing traffic.
The OFDMA has the most flexible Frequency Hopping approach “Magic Carpet” which is best utilised in frequency and allocation of resources in different region..

### 8.5. Public, Private and residential operators

| |
|---|
| It shall be possible to guarantee pre-determined levels of quality-of-service to public UMTS network operators in the presence of other authorised UMTS users. |

| |
|---|
| The radio access scheme should be suitable for low cost applications where range, mobility and user speed may be limited.<br>Multiple unsynchronised systems should be able to successfully coexist in the same environment.<br>It should be possible to install basestations without co-ordination.<br>Frequency planning should not be needed. |

Due to good commonality and flexible resource allocation and advance frequency hopping public, private and residential operation is supported. This include support of unsynchronised multiple system with the usage of DCA.
Low cost terminals with a restricted set of functionality can be implemented. For example, limited bit rate, power output for private cordless telephone applications.

# 9. Efficient Spectrum Usage

## 9.1. Spectral Efficiency

| |
|---|
| High spectrum efficiency for typical mixtures of different bearer services<br>Spectrum efficiency at least as good as GSM for low bit rate speech |

The spectral efficiency is considered in detail in evaluation report.
The results shows that for all service spectrum efficiency is achieved and in all cases greater efficiency than GSM.

## 9.2. Variable asymmetry of total band usage

| |
|---|
| Variable division of radio resource between uplink and down link resources from a common pool (NB: This division could be in either frequency, time, or code domains) |

Thanks to OFDM, the variable asymmetric band usage is most efficient in OFDMA concept.

## 9.3. Spectrum utilisation

| |
|---|
| Allow multiple operators to use the band allocated to UMTS without co-ordination.<br>It should be possible to operate the UTRA in any suitable frequency band that becomes available such as first & second generation system's bands |

Spectrum sharing requires further study (as noted in ETR 04-01)

OFDMA can be deployed for some applications using a single as little as 800 KHz - 1.6MHz bandwidth (e.g. isolated cell). A small network could be deployed in as little as 3.2MHz. OFDMA spectrum utilisation is most efficient with minimum Guard Band requirements.

## 9.4. Coverage/capacity

| |
|---|
| The system should be flexible to support a variety of initial coverage/capacity configurations and facilitate coverage/capacity evolution<br>Flexible use of various cell types and relations between cells (e.g. indoor cells, hierarchical cells) within a geographical area without undue waste of radio resources.<br>Ability to support cost effective coverage in rural areas |

### 9.4.1. Development and implementation risk

The OFDMA is the most flexible UTRA concept known today, which supports variety of initial coverage and capacity most effectively with the available resources.

### 9.4.2. Flexibility of radio network design

#### *9.4.2.1. Cell size flexibility*

The OFDMA transmission bursts are designed to cover a wide range of channel conditions. This allows operation in picocells, microcells and macrocells. Hierarchical Cell Structures are supported.

#### *9.4.2.2. Cell location flexibility*

The Interference Averaging concept means that the system performance is not critically sensitive to base station location

#### *9.4.2.3. Synchronisation*

Time synchronisation between different UMTS networks is desirable to optimise spectrum efficiency For both FDD and TDD), but is not essential. Pseudo synchronisation is desirable in TDD mode.

#### *9.4.2.4. Very large cell sizes*

Very large cell sizes can be supported (for example by increasing the number of slots allocated to the bearer). Details of other techniques which could be employed, such as adaptive antennas, RF repeater stations or remote antennas are for further study.

#### *9.4.2.5. Evolution requirements*

##### 9.4.2.5.1. Coverage evolution

The OFDMA with flexible resource allocation is most efficient in evolution coverage.

##### 9.4.2.5.2. Capacity evolution

Similarly, a minimum of planning is needed in order to install new cells to increase system capacity in areas where coverage is already provided.

# 10. Complexity / cost

## *10.1. Mobile Terminal viability*

| |
|---|
| Handportable and PCMCIA card sized UMTS terminals should be viable in terms of size, weight, operating time, range, effective radiated power and cost. |

Due to low complexity of OFDMA and low MIPS, the cost of terminal is extremely low. Low cost terminals (speech only) is most feasible in OFDMA concept.

## *10.2. Network complexity and cost*

| |
|---|
| The development and equipment cost should be kept at a reasonable level, taking into account the cost of cell sites, the associated network connections , signalling load and traffic overhead (e.g. due to handovers). |

OFDMA provides a single radio interface concept which can be adapted to all operating environments.

## *10.3. Mobile station types*

| |
|---|
| It should be possible to provide a variety of mobile station types of varying complexity, cost and capabilities in order to satisfy the needs of different types of users. |

Mobile stations can easily be implemented with various complexity/cost/capability trade-offs. For example, low data rate terminals for both GSM and UMTS (multiband/mode) is most economical in OFDMA.

# 11. Requirements from bodies outside SMG

## 11.1. Alignment with IMT 2000

| |
|---|
| UTRA shall meet at least the technical requirements for submission as a candidate technology for IMT 2000 (FPLMTS). |

These requirements are fulfilled.

## 11.2. Minimum bandwidth allocation

| |
|---|
| It should be possible to deploy and operate a network in a limited bandwidth |

The minimum bandwidth for small cell is 1.6 MHz.
The minimum system bandwidth is 5 MHz.

## 11.3. Electromagnetic compatibility

| |
|---|
| The peak and average power and envelope variations have to be such that the degree of interference caused to other equipment is not higher than in today's systems. |

The peak power and envelope variations can be constrained so that interference is expected to be less severe than (or at least comparable) with GSM

## 11.4. RF Radiation effects

| |
|---|
| UMTS shall be operative at RF emission power levels which are in line with the recommendations related to electromagnetic radiation. |

Details of emission levels are for further study.
For ease of implementation, a maximum transmitter output power of around 1W peak is considered desirable for hand portable units.

# 12. Security

| |
|---|
| The UMTS radio interface should be able to accommodate at least the same level of protection as the GSM radio interface does. |

At least supports the same level Security as in GSM, however these issues are for further study in SMG2.

# 13. CO-existence with other systems

| |
|---|
| The UMTS Terrestrial Radio Access should be capable to CO-exist with other systems within the same or neighbouring band depending on systems and regulations |

Coexistence with other system in OFDMA is most efficient due to low Guard band requirements and most efficient spectrum utilisation. The OFDMA produces the minimum co., and adjacent channel interference.

# 14. Multimode terminal capability

| |
|---|
| It should be possible to implement dual mode UMTS/GSM terminals cost effectively. |

With backward compatibility with GSM system, multimode terminal is most efficiently implemented and it is the most cost effective terminal.

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Madrid, Spain
December 15th-19th, 1997

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Source: SMG2
Agenda Item: 4.1 UTRA
Subject: Evaluation Document SMG2 - Beta Concept

# Concept Group Beta
# OFDMA (Orthogonal Frequency Division Multiplex Access)
# System Description Performance Evaluation

**Disclaimer:**
"This document was prepared during the evaluation work of SMG2 as a possible basis for the UTRA standard. It is provided to SMG on the understanding that the full details of the contents have not necessarily been reviewed by, or agreed by, SMG2."

# *OFDMA Evaluation Report*

## The Multiple Access Scheme Proposal for the UMTS Terrestrial Radio Air Interface (UTRA)

## Part 1
## System Description
## Performance Evaluation

***Summary:***

This document describes in detail the OFDMA (Orthogonal Frequency Division Multiple Access) radio interface. This system is proposed for the radio interface for the third generation system (UMTS) in Europe. In addition, results are provided for both link and system level simulations.

The Evaluation Report consist of 3 parts:
Part 1: System Description and Performance evaluation
Part 2: Link Budget Templates and Technology Description Template
Part 3: Frequently Asked Questions

# Table of Contents

# 1. OFDMA System Description

The most important aspects of the physical layer are the time/frequency structure and the OFDM parameters. The following table summarises the common parameters and key technical characteristics of the OFDMA air-interface.

**Table 1: Physical Parameters**

| | Parameter | Value |
|---|---|---|
| 1 | Sub-carrier spacing $f_{SC}$ [Hz] | 100[kHz]/24 = 4.1666[kHz] |
| 2 | Effective modulation period $T_M$[sec] | 1/fsc = 240[μs] |
| 3 | Number of sub-carrier per band slot | 24 sub-carriers ( 100[kHz] ) |
| 4 | Modulation period | 60[ms]/13/16 = 288.46[μs]<br>( Half of GSM time slot ) |
| 5 | Time slot length $T_{TS}$[sec] | 60[ms]/13/16 = 288.46[μs]<br>( Same as Modulation period ) |
| 6 | Tx window shape | Full cosine roll off ( Tukey ) |
| 7 | Ramp period $T_R$ [sec] | 10[μs] |
| 8 | Pre-Guard time $T_{G1}$[sec] | 38-a[μs] |
| 9 | Post-Guard time $T_{G2}$[sec] | a[μs]<br>*Proposal a=8.0μs* |
| 10 | Modulation unit | Consists of 1 band slot and 1 time slot |
| 11 | Modulation block | 4 time slots and 1 band slot |

# 2. OFDMA System Features

The following summary shows some advantages of the OFDMA UTRA proposal.

- Single core PHY layer minimizing hardware costs with 2 software driven MAC options
- SFH TDMA based MAC for majority of UMTS services
- TDD DCA MAC for unpaired spectrum allocations, asymmetrical services & unlicensed usage
- Adaptive Modulation schemes for different channels
- Robustness against multi-path and Doppler spread
- Low computational overheads
- Simple low cost low-bit rate only terminals feasible
- Straightforward and efficient high bit rate support
- Small guard band requirements ~ 100 kHz
- High Spectral Efficiency achievable - 2 Mbits/s in 1.6 MHz feasible
- No frequency planning option available - effective re-use factor of ~1
- GSM Backwards Compatibility
- Minimum Bandwidth Requirements for system deployment only 1.6 MHz (or less) and deployment possible in steps of 100kHz
- Standard TDMA cellular planning and system enhancement techniques (smart antennas, hierarchical cell structures) can be supported

# 3. OFDMA Logical Channels

OFDMA logical channel will follow the standards set in ITU and ETSI. In this section the logical channels for the OFDMA system are defined.

## 3.1 Common Control Channels

### 3.1.1 IACH (DL)

The IACH is the initial acquisition channel used for time and frequency synchronisation. In addition the IACH channel conveys information about the allocation of the BCCH channels. The IACH channel is a knowledge enclosed reference operation (KERO) burst (Figure 2) which includes 11 pilot symbols in order to ease detection. A KERO detector consists of a comb filter and correlator (Figure 3). IACH carries a 15 bit random sequence seed and can also be used for neighbour cell search for Mobile Assisted Hand Over (MAHO).

### 3.1.2 BCCH (DL)

The Broadcast Control Channel is a point-to-multipoint channel providing cell specific system information. The burst type of BCCH is a normal differential burst (Frequency Domain Differential Encoded). BCCH's information is convolutionally encoded ( R = 1/3 ) and interleaved ( block interleaving ) over 64 BCCH bursts.

**Allocation of IACH and BCCH bursts**
Figure 1 shows IACH and BCCH allocation in the time and frequency domains. IACH bursts are allocated every 16 band slots ( fixed at every 1.6 MHz).

The IACH burst carries a 15 bit random sequence seed which is updated. This random sequence is split into three parts R1, R2 and R3 each consisting of 5 bits. R1 and R2 dictate which bandslot a BCCH burst will be allocated. The first BCCH burst after the IACH burst is allocated 3 timeslots later and R1 bandslots higher: The second BCCH burst is allocated 6 timeslots later and R2 bandslots higher. The third part of the random number, R3, dictates when the IACH burst will be transmitted. The next IACH burst is transmitted at 64 + R3 timeslots later on the same bandslot.

If system band is wider than 1.6[MHz] the same structure and contents of IACH and BCCH will be transmitted at 9 timeslots later on a 1.6[MHz] higher band. This ensures reception of the IACH and BCCH bursts.

All the base stations transmit IACH and BCCH bursts using the same scheme. The random numbers ( R1, R2, R3 ) are independent and therefore there is a low probability ( 3/16BS/64TS = 0.3[%] ) of collision.

No specific frequency channels are allocated for IACH and BCCH and therefore no management is required when using the same band in each cell. IACH and BCCH are also transmitted independently from the other channels (TCHs, etc.). When IACH and BCCH transmit at the same time and same bandslot as an active channel, the active channel is punctured.

**MS actions**
After the initial MS power on, the MS tunes to the bandslot which may transmit IACH channel (every 1.6[MHz] ) and sets KERO detector active. If no signal is received, it is concluded that the system is not operated in the frequency band or the location is out of service area.
If the system is operated, KERO detector will detect all IACHs transmitted by BSs which are located close to the MS.
MS select BS with the highest IACH signal , decodes 15 bits random seed in the IACH.
Now the MS can tune to the BCCH.
Once IACH is detected, MS will not loose the position of future IACH and BCCH because the locations can be calculated uniquely by updating random number.

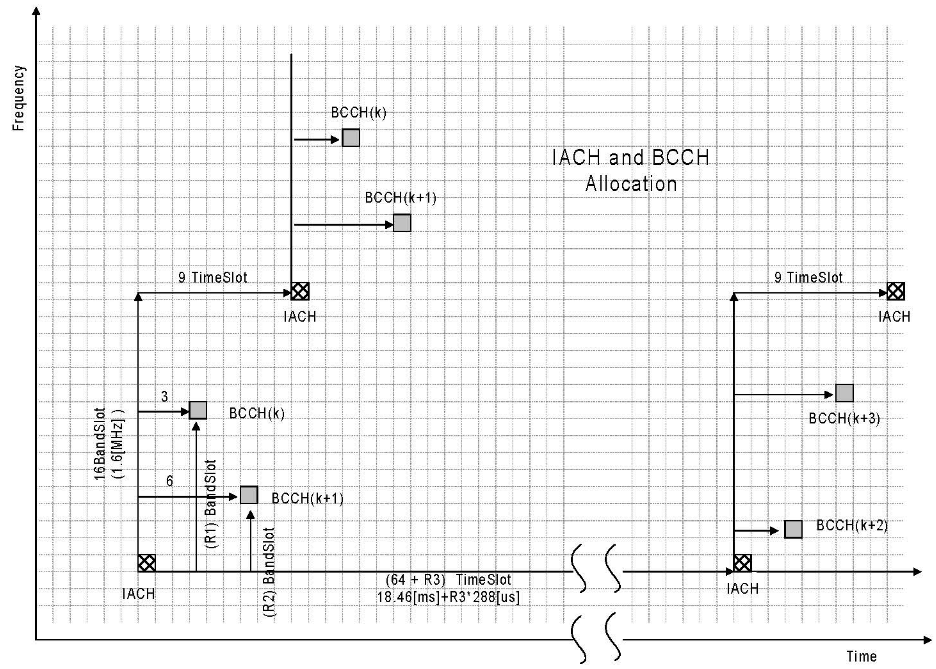



**Figure 1: Location of IACH and BCCH channels**

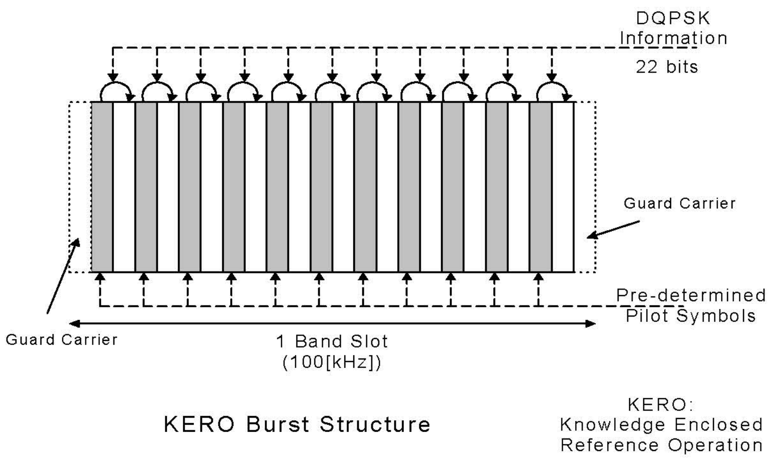



**Figure 2: KERO burst structure**

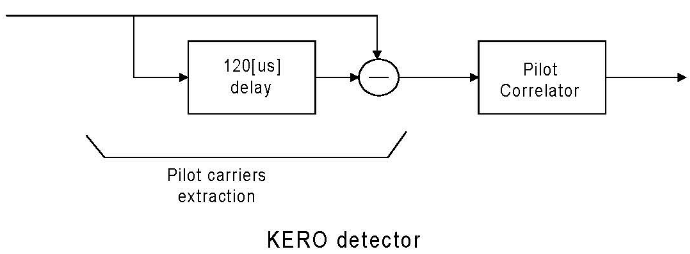



**Figure 3: KERO detector**

## 3.1.3 RACH ( Random Access Channel ) Physical Structure

The Random Access Channel is an uplink channel, carrying the information from the mobile station.

**RACH burst**

KERO burst (Figure 2) is also used for the RACH burst which can be detected by KERO detector in the BS. RACH carries a Random Access Number (RAN) which consists of 7 bits related to the Mobile Station Identification (MSID) number.

**Allocation and Power Control of RACH**
Two continuous time slots are prepared for the RACH burst, because propagation delay is unknown before communication starts between MS and BS. The RACH burst will be transmitted at the same power which was estimated as the down link signal strength (Open Loop Power Control) based on the received IACH and BCCH information.

**MS and BS actions**
MS measures RSSI and calculates adequate transmit power.
MS transmit RACH burst at calculated power and timing where a propagation delay of 0[μs] is assumed.
BS detects RACH using KERO detector and then decodes the RAN.
If detection and decoding was done successfully, BS reports back the RAN and time alignment value and location of DCCH (Dedicated Control Channel) through AGCH (Access Grant Channel) to the MS.
MS listens to AGCH, if the RAN corresponds to the RAN of the mobile, assignment of DCCH can be confirmed.
If the RAN is not detected, MS will transmit RACH again.

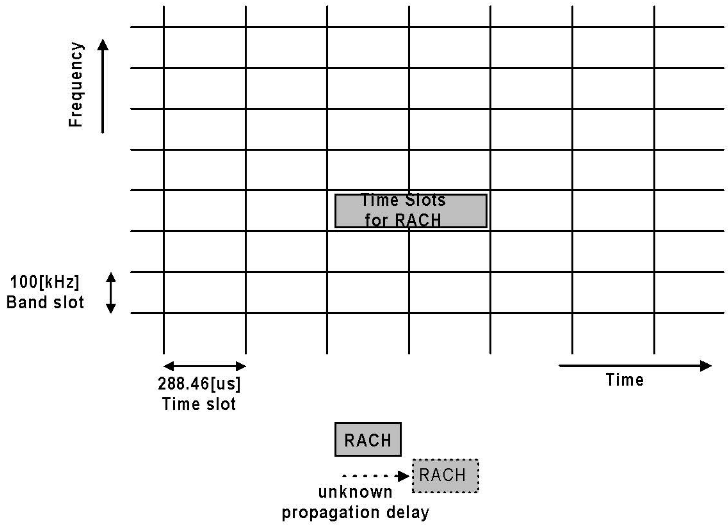



**Figure 4: RACH Structure**

### 3.1.4 PCH(DL)

The Paging Channel is a downlink channel that is used to carry information to a mobile station. It can also be used for location update of mobile stations.

## 3.2 Dedicated Channels

**DCCH (DL & UL)**
The dedicated control channels are bi-directional and are used to carry control information to- and from the mobile station to the network.
**TCH (DL & UL)**
The traffic channels are bi-directional or unidirectional channels which are used to carry the user information (Speech, data) between the network and mobile station.

**AGCH**
The Access Grant Channel reports TCCH allocations and timing advance information for specific MSs.

# 4. OFDMA Resource Allocation/Physical Channel

## 4.1 Time and Frequency Parameters

The OFDMA air-interface utilises a time and frequency grid for basic physical channel structure.

Figure 5 shows the modulation blocks in the time and frequency grid. The resources (time and frequency) are allocated based on the type of services, operational environment/scenarios (i.e. give more flexibility). There are four mode of resource allocations:-

a) 1 x time slot + 1 x band slot
b) n x time slots + 1 x band slot
c) 1 x time slot + n x band slots
d) n x time slots + n x band slots

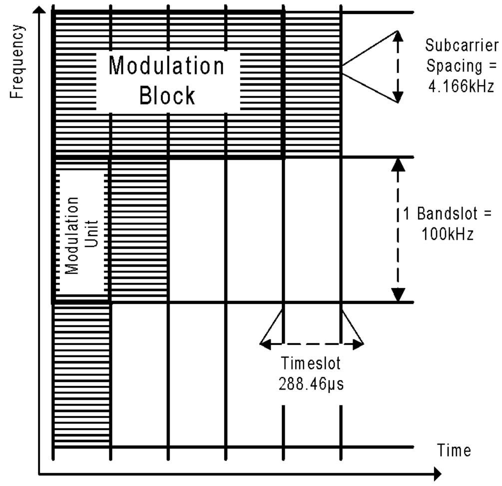



**Figure 5: Time and frequency grid**

The TDMA frame structure is shown in Figure 6. Each frame is of length 4.615 ms which is divided into 4 sub-frames of length 1.1534 ms. A sub-frame contains 4 time slots of duration 288.46 µs. The timeslot contains a guard period, power control information and data. Every OFDM symbol is mapped onto one time slot.

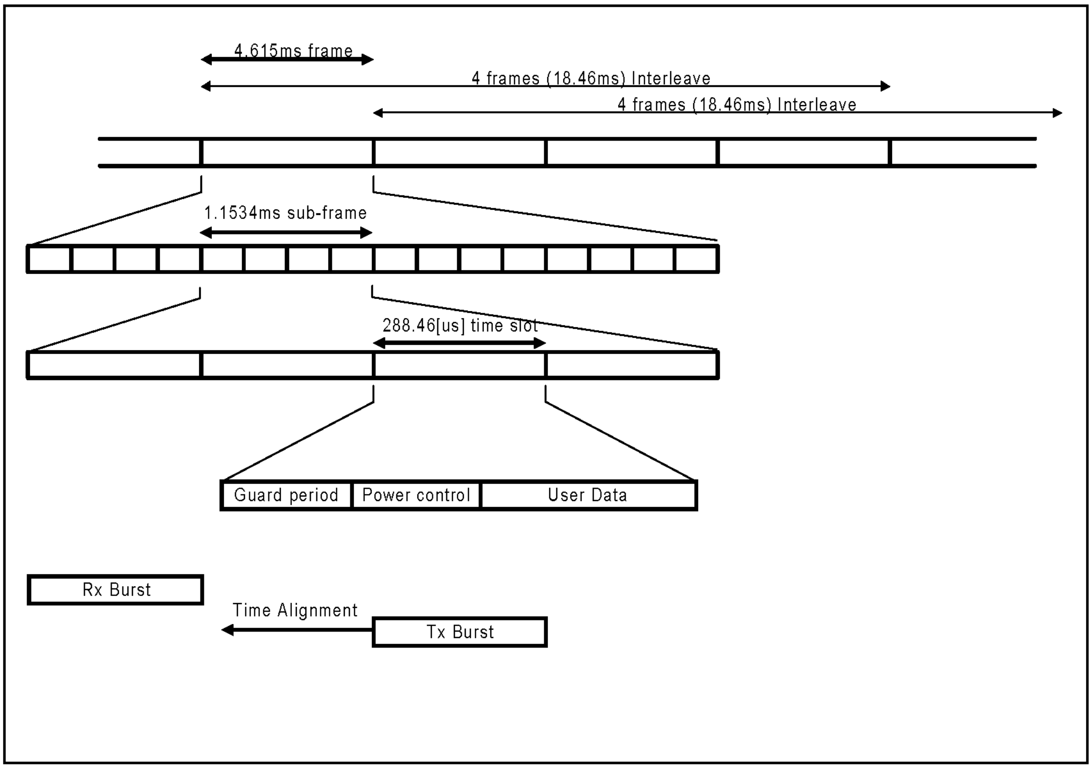



**Figure 6: Frame (TDMA) Structure**

The Guard time is applied to be robust against very long multi-path delay. Tx windowing shape is full cosine roll off (Tukey window ), this reduces adjacent band emissions effectively. Figure 7 shows the shape of the modulation unit.

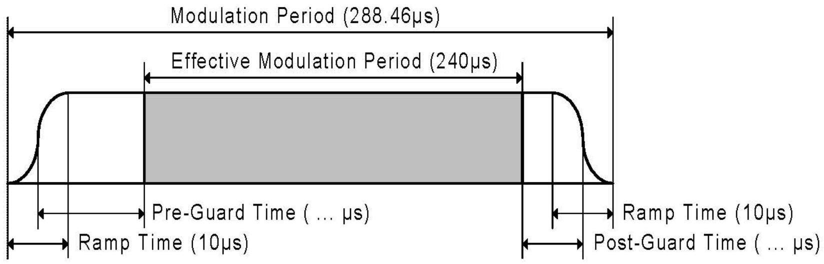



**Figure 7: OFDM Modulation Burst**

The whole system frequency band is divided into small blocks (bandslots) with a fixed number of subcarriers. To maintain compatibility with GSM a bandslot of 100kHz is chosen which consists of 24 subcarriers. Therefore the subcarrier spacing is $\frac{100}{24}[kHz] = 4.167[kHz]$.
In each bandslot the two subcarriers at the edge of the bandslot are left unmodulated to relax receiver blocking requirements. In addition, the interference of two adjacent blocks of subcarriers is reduced, which may occur when their orthogonality is compromised due to non-linear PA effects.

Adjacent bandslots can be concatenated to allow transmission of wideband services.

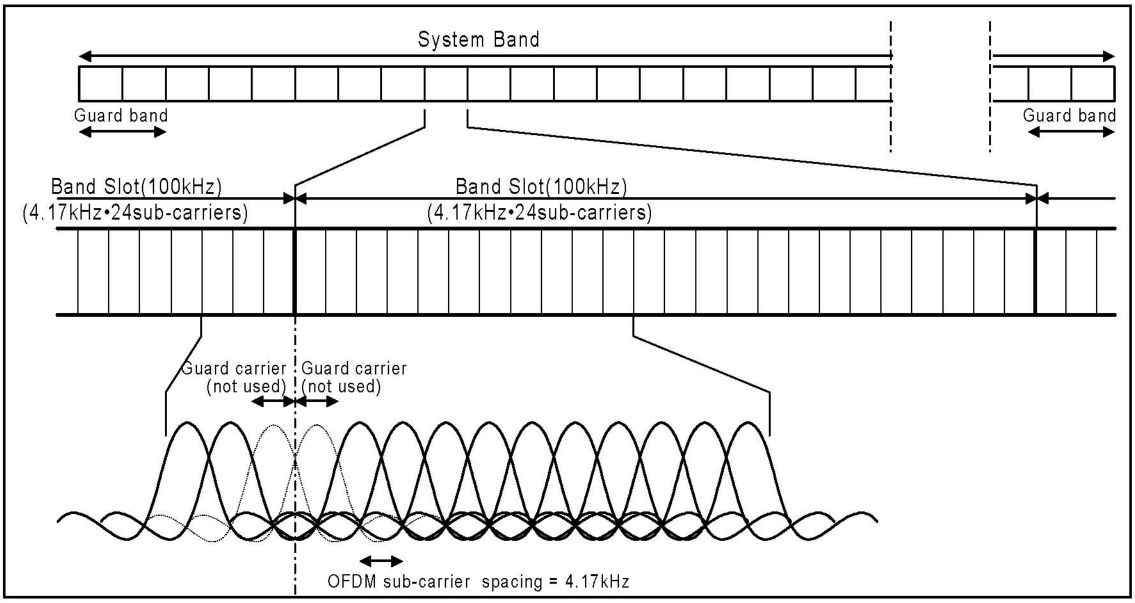



**Figure 8: BDMA Frequency Structure**

## 4.2 Multiple Access (Physical Channel Assignment)

The OFDMA utilises the time division multiple access with the aid of slow and fast dynamic channel allocation. Additionally frequency division multiple access (FDMA) is used with variable bandwidth.

## 4.3 Un-modulated Guard Carriers

In order to reduce adjacent channel emissions and facilitate easy bandslot separation one subcarrier at the edge of the bandslot is left unmodulated.

Figure 9 depicts the scheme.

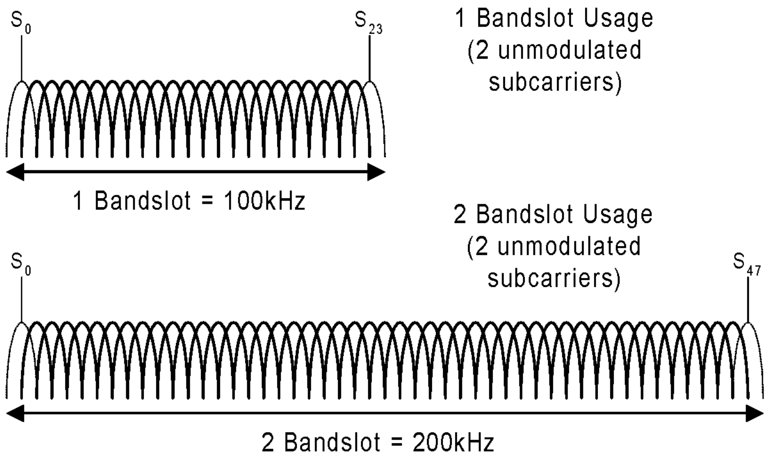



**Figure 9 : Guard Carrier Allocation**

## 4.4 Antenna Diversity

Receiver antenna diversity is utilised at the BS and the MS. Maximum ratio combining (MRC) is used to combine the two separate baseband signals after demodulation and is used with confidence weighting to form the received soft decision bits.

# 5. Radio Functions

## 5.1 Channel Coding

### 5.1.1 Convolutional Encoding

Convolutional encoding and soft decision Viterbi decoding is utilised for the basic data transmission. The objective of this coding is to achieve good quality in the tough mobile radio channel. A constraint length of 7 together with variable coderates in the range of 1/4 to 3/4 (according to channel characteristics and modulation scheme) are proposed. Fine tuning of the bit rates is achieved by puncturing during the interleaving and mapping of modulation symbols onto OFDM subcarriers.

**Table 2: Basic Code Rates**

| Constraint length K | Coding rate R |
|---|---|
| K = 7 | R = ¼ |
| K = 7 | R = 1/3 |
| K = 7 | R = ½ |
| K = 7 | R = 3/4 (punctured 1/2) |

### 5.1.2 Reed Solomon Coding and Concatenated Coding

To achieve very low bit error rates ( e.g. 10e-6) for video encoding or data transmission Reed Solomon encoding is effective. This coding will be concatenated with an inner convolutional encoder.

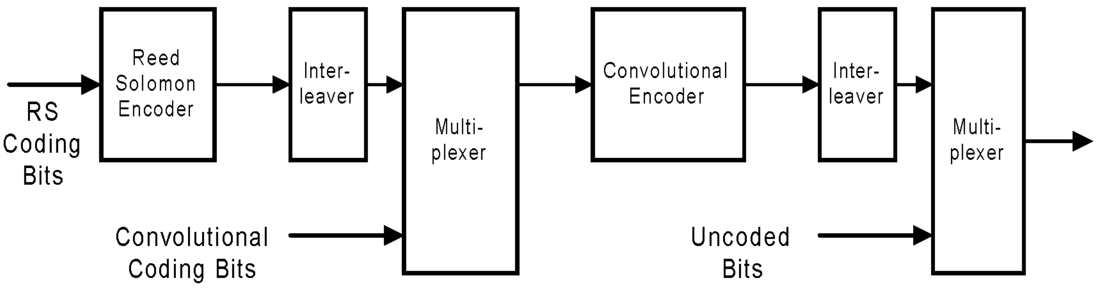



**Figure 10: Encoder Structure**

### 5.1.3 Turbo Coding

[For Further Study]

## 5.2 Interleaving

Interleaving is utilised so the channel coding performs well in the presence of burst errors caused by the fading channel. Interleaving length depends on the service related specified delay constraint.

## 5.3 Modulation and Demodulation Schemes

### 5.3.1 Coherent Modulation

While differential detection is the simplest to implement, the advantages of coherent detection over differential detection are a gain of about 2 dB in signal-to-noise ratio and the possibility to do higher order QAM, such as 16-QAM. Disadvantages are a more complex implementation and the presence of extra pilot symbols. Efficient pilot patterns and channel estimation techniques have been described in [SMG2 TD 116/96, 'A conceptual study of OFDM-based multiple access schemes', Telia Research, 22 May 1996]. In the case of indoor use, the relative delay spread and Doppler bandwidth are so small that a simplified scheme is possible, which uses a pilot pattern as depicted in the following figure. Only one out of every 16 subcarriers is a pilot, so the training overhead is 6.25%. In the receiver, reference values for each subcarrier can be obtained by simply averaging the 4 closest pilots. This procedure was used in the evaluation of the indoor scenario.

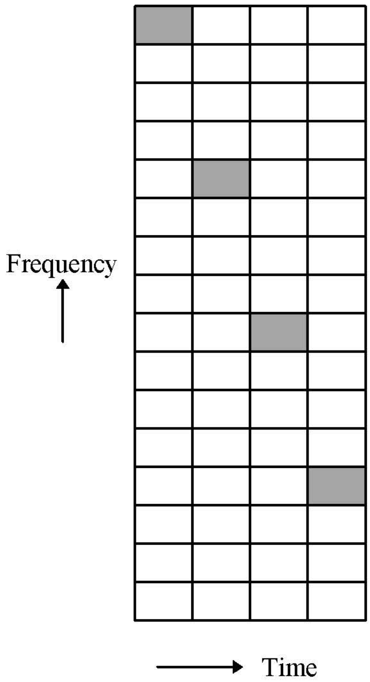



**Figure 11: Time and frequency grid showing OFDM pilot symbols**

### 5.3.2 Differential Modulation

Differential modulation will facilitate easy implementation and stable processing. The proposed schemes are differential QPSK and differential 8PSK. 8PSK combined with a lower coding rate will accommodate the highest data rate requirements in the UMTS.
The modulation scheme is Frequency Domain Differential Encoding (e.g. FD-DQPSK, FD-D8PSK).
Each bandslot contains its own reference symbol.

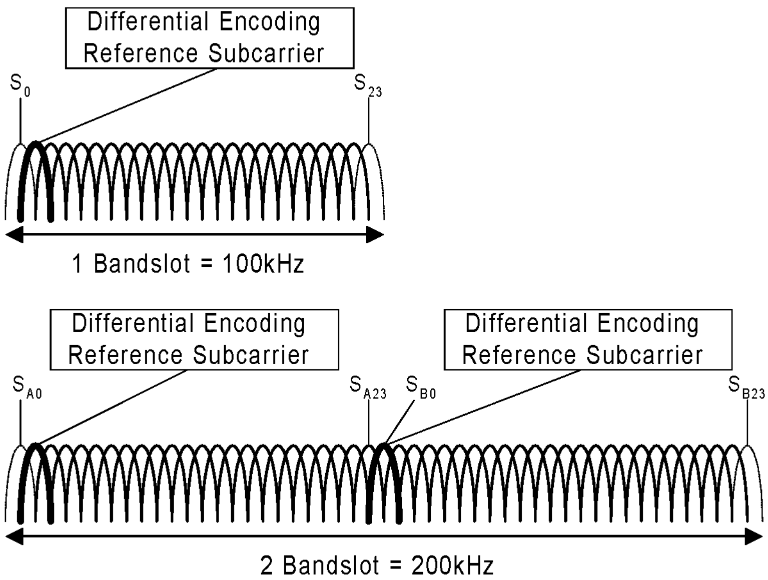



**Figure 12: Reference Subcarrier Allocation**

## 5.4 Random Phase Shift Technique (RPS)

This technique helps to 'randomise' interference and enables the differential detector to distinguish 'desired' signal from interfering signal. Receiver structures have been developed to estimate the received $\frac{S}{(N+I)}$ and apply this information as confidence weights to the soft decision demodulated bits before Viterbi decoding.

A random phase sequence is applied to the differential M-ary PSK symbols after differential encoding before IFFT.

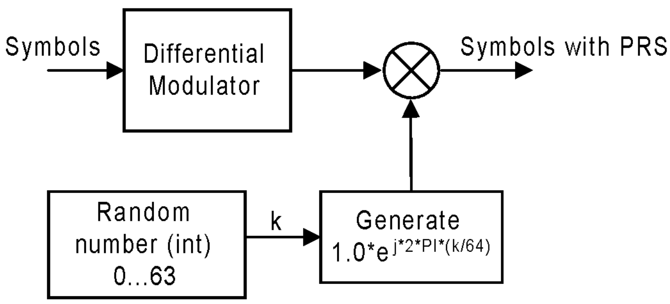



**Figure 13: Random Phase Shift Technique**

The random sequence is different for different cells and unique within the cell (the possibility to use different sequences within one cell is also possible). The receiver can perform an de-rotation (cross-correlation) of the received RP-shifted symbols with the know RPS sequence to recover the original sequence.
This technique is applied to all communications after the initial communication set-up phase.

## 5.5 Random Orthogonal Transform (ROT)

The Random Orthogonal Transform (ROT) technique is an enhancement of the RPS technique to randomise interference in order to improve the demodulation process. It is based on small matrix transformation in the transmitter and receiver. The following section describes briefly this technique.

### 5.5.1 Transmitter Procedures

The adjacent symbols (already differentially encoded) are named $x_0$ and $x_1$, the resulting symbols are named $y_0$ and $y_1$.

For simplification we define: $rot(\vartheta) = e^{j2\pi\vartheta}$

We perform the following calculation to obtain the resulting symbols $y_0$ and $y_1$:

$$y_0 = \frac{1}{\sqrt{2}}\left(x_0 + x_1\right)\cdot rot(\Theta_0) \qquad y_1 = \frac{1}{\sqrt{2}}\left(x_0 - x_1\right)\cdot rot(\Theta_1) \qquad or \qquad \begin{pmatrix} y_0 \\ y_1 \end{pmatrix} = \begin{pmatrix} \frac{1}{\sqrt{2}} rot(\Theta_0) & \frac{1}{\sqrt{2}} rot(\Theta_0) \\ \frac{1}{\sqrt{2}} rot(\Theta_1) & \frac{-1}{\sqrt{2}} rot(\Theta_1) \end{pmatrix} \begin{pmatrix} x_0 \\ x_1 \end{pmatrix}$$

With the definition of the transformation matrix *R:* $R = \frac{1}{\sqrt{2}}\begin{pmatrix} rot(\Theta_0) & rot(\Theta_0) \\ rot(\Theta_1) & -rot(\Theta_1) \end{pmatrix}$

The matrix transformation we perform can be written as: $\begin{bmatrix} y_0 \\ y_1 \end{bmatrix} = R \cdot \begin{bmatrix} x_0 \\ x_1 \end{bmatrix}$

### 5.5.2 Receiver Procedures

In order to demodulate the incoming signal correctly the receiver performs the inverse operation.
The used Matrix in the receiver is called $R^{-1}$ with:

$$R^{-1} = \frac{1}{\sqrt{2}}\begin{pmatrix} rot(-\Theta_0) & rot(-\Theta_1) \\ rot(-\Theta_0) & -rot(-\Theta_1) \end{pmatrix}$$

We can also write:

$$z_0 = \frac{1}{\sqrt{2}}\left(y_0 \cdot rot(-\Theta_0) + y_1 \cdot rot(-\Theta_1)\right) = \tfrac{1}{2}(x_0 + x_1) + \tfrac{1}{2}(x_0 - x_1) = x_0$$

$$z_1 = \frac{1}{\sqrt{2}}\left(y_0 \cdot rot(-\Theta_0) - y_1 \cdot rot(-\Theta_1)\right) = \tfrac{1}{2}(x_0 + x_1) + \tfrac{1}{2}(-x_0 + x_1) = x_1$$

Using the described matrix operation the original information symbols can be correctly recovered and the interfering signal can be efficiently randomised.

## 5.6 Time and Frequency Synchronisation

Synchronisation is an essential issue for the OFDMA system. The following aspects are considered for uplink and downlink: Initial modulation timing synchronisation, modulation timing tracking, initial frequency offset synchronisation and frequency tracking.

The special structure of the OFDMA system which separates users in time and frequency (bandslots) simplifies the accuracy requirements for synchronisation compared to other OFDM systems. The OFDMA scheme provides good synchronisation performance compared to single carrier modulation, the basis is the guard time which is required to mitigate multipath effects.

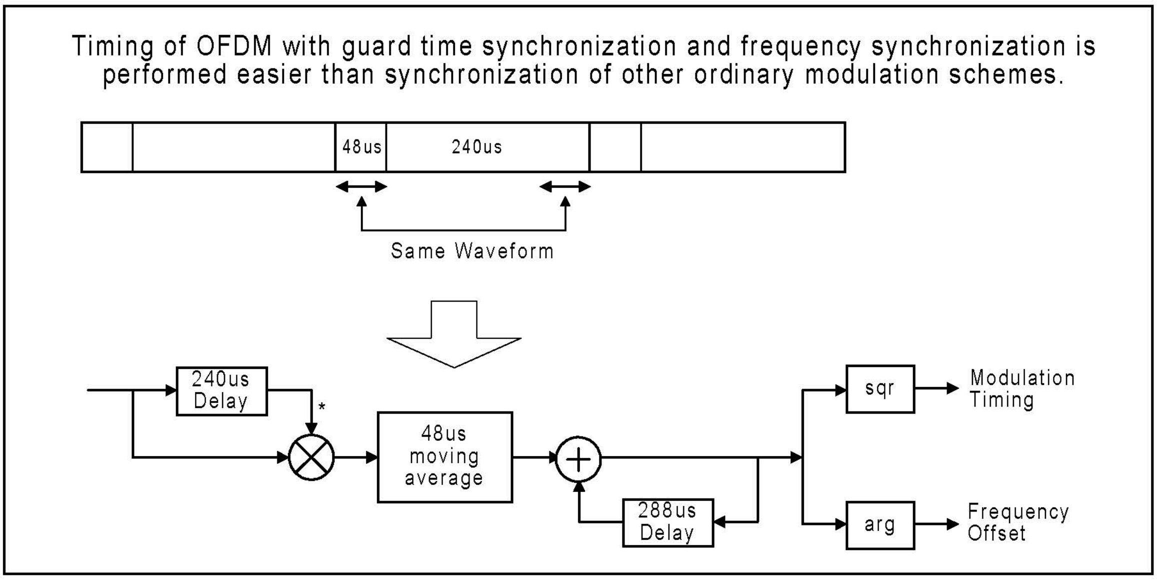



**Figure 14: Synchronisation (Schematic)**

## 5.6.1 Initial Modulation Timing Synchronisation (Downlink)

Initial timing synchronisation is required to adjust the MS internal timing to the basestations time frame. After switching on, the mobile station monitors the IACH channel and the BCCH channel.

The modulation burst in the OFMDA system consists of an OFDM symbol with an additional cyclic extension (copy of a portion of the time signal). In the receiver the structure of the burst can be detected by autocorrelation of the time domain signal. Using multiple bursts for the correlation (averaging) the accuracy of the timeslot structure in tough radio environments with low S/N, low C/I and fading channels can be improved. Once the timeslot structure is detected an additional detection of the systems frame structure can be achieved.
The initial, still undetected frequency offset does not significantly degrade the performance of the correlation algorithm.

The correlation equation is $p(k) = \sum_{1}^{K} s^*(k) \bullet s(k - T_{OFDM})$ where p(k) is the complex correlation value and is the summation over the available guard samples. $T_{OFDM} = \frac{1}{f_{SC}}$. where $f_{SC}$ is the subcarrier spacing. If the samples are equal (copy) the correlation value is high, in other regions (the OFDM signal is almost noise like) the correlation values are low.

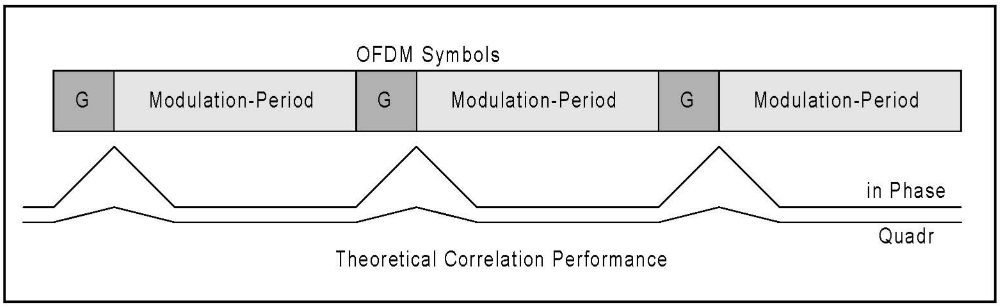



**Figure 15: Theoretical Time Synchronisation Performance (Correlation)**

The theoretical behaviour of the correlation based timing detection (synchronisation) is depicted in Figure 15, the figure shows also the effect of a frequency offset (small peaks in the q-path).

Figure 16 shows the performance in the Vehicular channel B model. The S/N ratio was 5.0 dB with no interference and no frequency offset. Summation over multiple slots gives superior accurate timing detection.

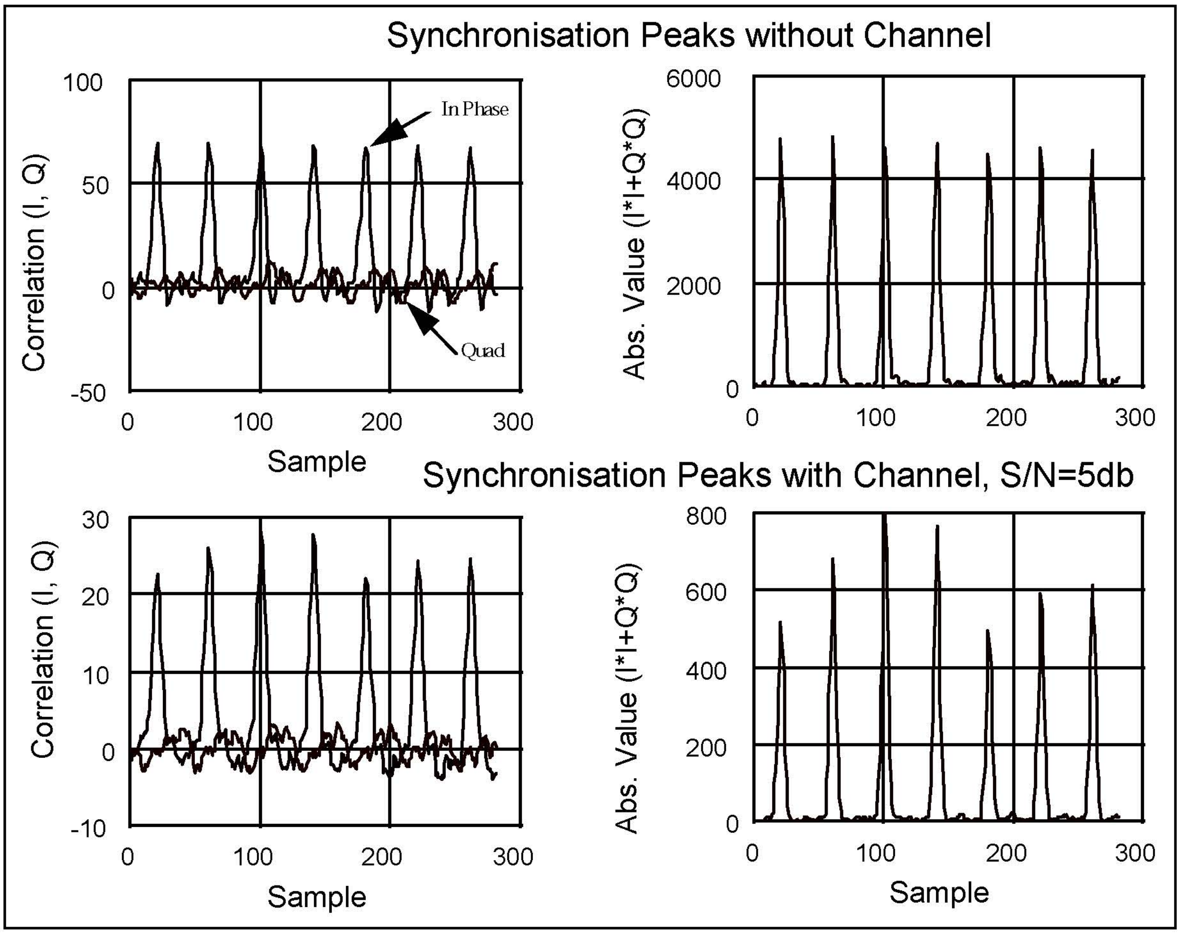



**Figure 16: Time Synchronisation in typical fading channel environment**

## 5.6.2 Initial Modulation Timing Synchronisation (Uplink)

After the mobile has detected the basestations timing it sends an RACH to the basestation. The BS measures the time offset for the received RACH and sends back the necessary timing advance to the MS (very similar to GSM). In the frame structure of the OFDMA system reserved slots for reception of RACH exist.

## 5.6.3 Modulation Timing Tracking (Uplink & Downlink)

Due to the time and frequency structure of the OFDMA system the timing tracking is less critical compared to other OFDM systems where users are interleaved in the frequency domain. The basestation can measure the position of the received OFDM burst within the allocated slot for each MS individually and send the according timing alignment information back to the mobile station.
Additionally, timing information can be refined after the transformation in the subcarrier domain.
In the mobile station the timing information is obtained and adjusted by the above mentioned correlation algorithm. Accurate timing information is required to determine the position of the 'useful' data samples within each burst so the FFT-window can be placed correctly. The guard samples relax the requirement for accurate timing because the position of the FFT window can be shifted within the guard time without performance degradation. Additional timing offset

correction can be performed to cope with the FFT window misplacements.

### 5.6.4 Initial Frequency Offset Synchronisation

After initial timing synchronisation of the mobile station, the frequency offset can be measured by phase comparison of the (ideally) equal time samples within each burst. Equal samples are placed in the guard interval of the OFDM burst. A phase rotation indicates an frequency offset. Using this technique a range of $-\frac{1}{2}f_{SC} \leq fo \leq +\frac{1}{2}f_{SC}$ can be detected. The initial offset will however extends this range and is detected using the specially designed symbols in the IACH channel.

### 5.6.5 Frequency Offset Tracking

After initial frequency synchronisation of the mobile station a frequency tracking algorithm calculates the offset within the range of $-\frac{1}{2}f_{SC} \leq fo \leq +\frac{1}{2}f_{SC}$. The offset information is fed back into the VC-TCXO of the down-converters. Our simulations compared different frequency tracking algorithms with realistic models of the VC-TCXO drift behaviour.

### 5.6.6 Synchronisation Accuracy

The proposed synchronisation acquisition and tracking algorithm is independent of the modulation scheme (coherent-non coherent, differential or coherent) and shows sufficient performance.
Therefore the same schematic applies to the coherent and non-coherent reception type of operation, no variations are necessary.
For coherent 16-QAM reception further processing in the frequency (subcarrier domain) is possible to further improve the performance. Frequency domain time tracking (or combined time-domain frequency-domain tracking algorithms) could be based on observing phase shifts of the known pilots within the time-frequency grid on the subcarrier domain which is very simple.

Some more explanations:

In the downlink only an IACH is multiplexed in order to allow fast and precise initial timing and frequency synchronisation. In the actual 'communication mode' the timing and frequency tracking is performed using the proposed, correlation based, synchronisation algorithm. In the uplink the rough timing offset is detected by the base station by measuring the arrival time of the RACH burst. This gives an initial time-advance value which is reported back to the mobile. During the communication the arrival time of the burst is detected by the base station using the proposed tracking algorithm (same as in the downlink) or an tracking algorithm in the frequency (subcarrier) domain, based on the detected constellation rotation.
The rotation can be explained by the Fourier transform equation:

$$F\left(g(t-t_0)\right) = F\left(g(t)\right)e^{-j\omega t_0}.$$

Both algorithms can also be combined. The alignment values are calculated regularly an reported to the MS. Accuracy requirements are relaxed because the design of the burst allows some overlapping arrival (another advancing feature of the raised cosine pulse shaping besides the reduction of out-of-band emission). Additionally the guard time helps to compensate timing misalignments.

The current burst design proposes a guard interval at the front and an additional guard interval at the back of the OFDM symbol, therefore an timing inaccuracy of ±10µs can be handled without any performance degradation. The resulting frequency domain constellation rotation, caused by timing misadjustments can easily be compensated after the FFT.

***Summary:*** *Timing misalignments in the range of ±10µs ca be allowed without performance degradation. Furthermore, timing errors of -20µs …+15µs can be allowed with negligible performance degradation.*

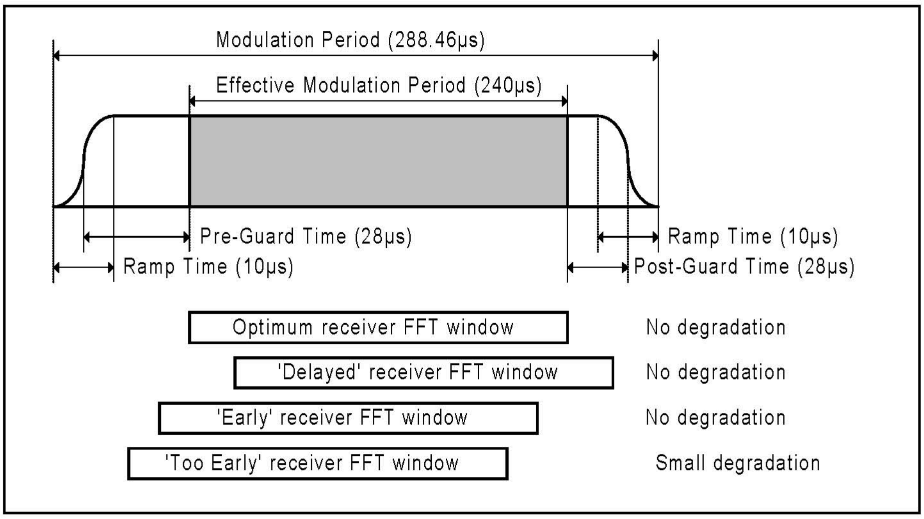



**Figure 17: OFMDA burst and synchronisation requirements**

## 5.7 PA Linearity

The envelope of the OFDM signal has a large variance. The complex envelope is approximated by a complex Gaussian distribution. The peak is extremely high, this generates problems for the physical realisation of the amplifiers (A linear-amplifier is expensive, especially for a (low-cost) hand portable terminal transmitters).

Simulations were therefore conducted to examine the power spectrum produced by a non-linear amplifier when transmitting an OFDM signal. The results are shown in Figure 18. These results are shown for different values of output back off (OBO) and are compared to GMSK and QPSK. The model for the amplifier includes the AM-AM and AM-PM distortions.(These distortions were taken from a real device.) The results show that for a reasonable value of OBO the power spectrum produced by the OFDM signal is comparable to other modulation schemes.

### 5.7.1 Interference to the Adjacent Band Signal

In the OFDMA system, the output power of each user is limited and controlled by a precise power control. Additionally, by back-off adjustment, the power spectrum density of distortion into adjacent band is at least 20dB lower than the signal power spectrum density.
In a typical environment, operation at maximum output power will be a rare case. In OFDMA, designed for operation under low S/N, the influence to adjacent bands is therefore expected to be small.

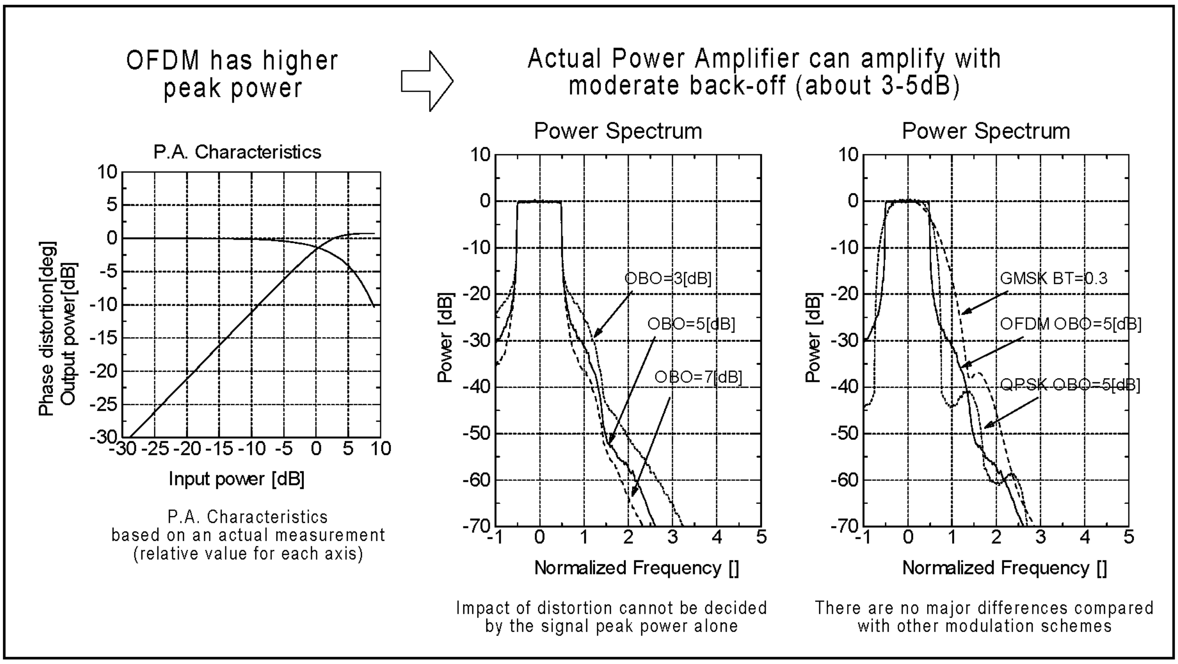



**Figure 18: Comparison of OFDM, GMSK and OFDM with non-linear PA**

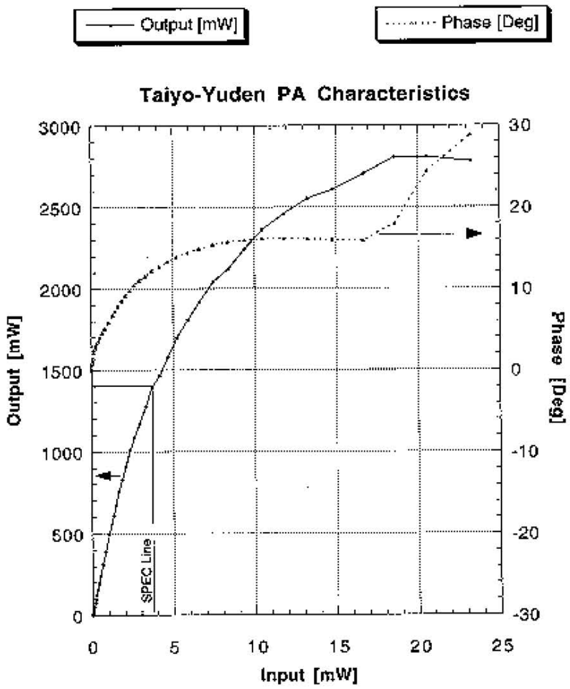
### 5.7.2 Reduction of OFDM Peaks

Several techniques are known to reduce the Peak-to-Average-Power (PAPR) of the OFDM signal. The PAPR can be expressed as $PAPR = 10 \cdot \log(N)$ where N is the number of subcarriers. The distribution shows that the probability of a high peak is very low.
The OFDMA system is designed to operate without any means to reduce the PAPR, but means to reduce the PAPR are considered as an option. Some well known techniques are: Special Coding, Soft-Clipping Windowing and Partial Transmit Sequences (see *Mueller97*).

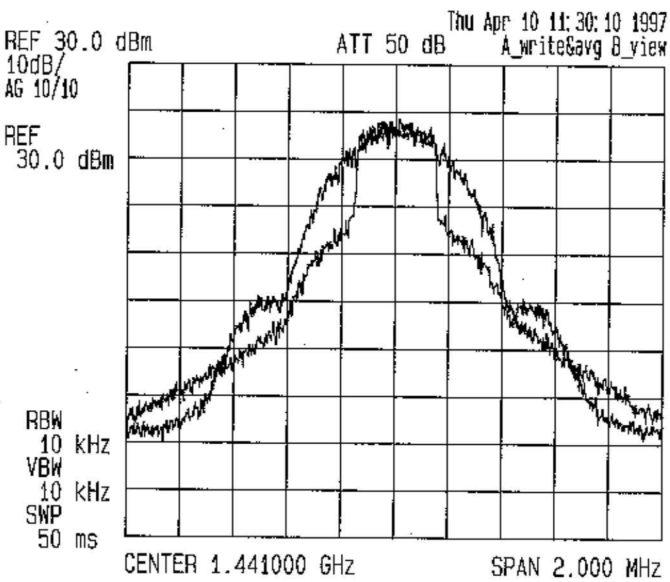
### 5.7.3 Real PA Nonlinearity Measurements

We measured the non-linear PA effects on currently available off-the-shelf PA for the Japanese PDC system (1.5GHz). The PA are used in handsets (cheap) and are not optimised for OFDM signals.
The graph shows the AM-AM and AM-PM conversion characteristics.
We used this amplifier and compared the non-linear effects for different modulation schemes (OFDM, GMSK, OQPSK,...).

Please note that the input-output characteristics is in the linear (not dB) scale.




The following figure shows the result of an actual measurement. We compare the spectrum of an OFDM signal (46 subcarriers) at an Output Back Off (OBO) of 3dB with an GMSK spectrum. The PA efficiency is shown in Table 3. The efficiency is 43.3% for the OFDM signal and 66% for the GMSK signal. The spectrum shapes are almost equal.




The conclusion is that OFDM signals, amplified with a small back off (3dB) have a comparable spectrum with GMSK signal. In addition the OFDM signal has a much smaller adjacent channel spurious emission.

Other measurement show similar result, the amplification of OFDM signals is not more critical compared to amplification of other signals using other modulation schemes.

**Table 3: Power Efficiency**

| Modulation Scheme | O.B.O.[dB] | power efficiency |
|---|---|---|
| GMSK | 0[dB]( saturated) | 66.0[%] |

| | | |
|---|---|---|
| OFDM | 3.0[dB] | 43.3[%] |

## 5.7.4 OFDMA receiver complexity (baseband)

The main complexity of the signal processing elements for the OFDMA receiver is the FFT. (This is ignoring the processing needed for channel decoding. To calculate the number of operations needed for the FFT, the analysis presented by McDonnell and Wilkinson [1] is used.
The size of the FFT needed at the receiver depends on the service required (scalability). For the case of the low date rate service (speech), only a 32 point FFT is required. This is sufficient for one band slot with 24 carriers and DQPSK modulation. For the highest data rate service (2 Mbit/s) we shall assume a bandwidth of 1.6 MHz and 8-DPSK modulation. This service requires a 512 point FFT.

The total number of real multiplications for an FFT is given by McDonnell[1]

$$2F\log_2 F$$

were $F$ is the size of the FFT. At the receiver an FFT has to be performed at the same rate as the time slot duration (288.46 µs). For speech only every fourth time slot is used so we shall derive an average and peak multiplications per second figure.
For speech therefore,

Peak no. of real multiplications per second = 2 x 32 x 5 x (1.0 / 288.46 x $10^{-6}$ ) = 1.109 x $10^6$

Average no. of real multiplications per second (1 FFT operation per frame) = 277.33 x $10^3$

For one frame (4*288.46µs=1.154ms) 2 IFFT operations (diversity reception) and 1 FFT (TX burst construction) are required. This results in 3*0.27733MOPS = 0.832 MOPS.

For the highest data rate (2 Mbit/s) service every 7 out of 8 time slots are used.

Peak no. of real multiplications per second = 2 x 512 x 9 x (1.0 / 288.46 x $10^{-6}$) = 31.94 x $10^6$

For one frame (8*288.46µs=2.307ms) 7*2 IFFT operations (7 used timeslots and 2 diversity reception) and 7 FFT (TX burst construction) are required.
This results in 3*(7/8)*31.94 MOPS = 83.9 MOPS.
This number can be reduced if only one Rx branch is used in the indoor environment (better C/I condition expected as compared to outdoor).

It is also important to note that the main processing element of the OFDMA receiver is a readily available FFT.
The following table summarizes the complexity of the FFT/IFFT processing. Please note the table gives ‘peak’ processing requirement which have to be divided by the acual used timeslots in the given TDMA structure.

| Bandwidth (kHz) | Subcarrier Number / FFT Size | Peak MOPS per single FFT / Peak MOPS: 2*RX, 1*TX |
|---|---|---|
| 100 | 24 (32) | 1.11 (3.3) |
| 200 | 48 (64) | 2.66 (7.98) |
| 400 | 96 (128) | 6.21 (18.6) |
| 800 | 192 (256) | 14.2 (42.6) |
| 1600 | 384 (512) | 31.95 (95.84) |

[1] J.T.E. McDonnell, T .A. Wilkinson, “Comparison of computation complexity of adaptive equaliser and OFDM for indoor wireless networks”, *Proceedings IEEE Personal Indoor Mobile Radio Conference (PIMRC) 1996, pp. 1088-1091*

# 6. Radio Maintenance Control

## 6.1 Timing Advance

The timing advance technique is required for OFDM based systems in order to maintain orthogonality of all of the up link signals. The accuracy requirements are similar to GSM, +/- 10µs are tolerable without performance degradation.

## 6.2 Handover

The exact algorithm and parameters used for handover are highly dependent on operational environment and network operators preferences. The standard handover algorithm is the base station originated handover with mobile assistance. However forward handover and MSC initiated handover are also supported.

### 6.2.1 Base Station Originated Hand Over

The following, lists the steps of a base station originated hand over.

When the mobile station X (MS-X) connected to base station A (BS-A) reports that it has detected the surrounding base station B ( BS-B ) :

1. BS-A asks BS-B to observe MS-X and inform BS-B about the hopping pattern of the MS-X.
2. BS-B sets its signal detector for detecting MS-X up link signal.
3. BS-A reports to MS-X detailed information of BS-B's and asks BS-B to prepare a handover of MS-X to BS-B. The following information is given:

   Propagation delay between the two base stations D(A,B)
   The estimated propagation delay between BS-B and MS-X called Tpd (BS-B, MS-X)
   The random phase shift pattern of BS-B.
   New hopping pattern and initial time and frequency slot of BS-B.
4. MS-X will receive BS-B's IACH to confirm the arrival time difference between BS-A and BS-B.
5. BS-B also measures the RSSI of MS-x's up link signal and compares the RSSI with the RSSI of the MSs connected to BS-B (RSSIref). When MS-X's RSSI exceed the RSSIref.

   BS-B asks BS-A to hand over MS-X.
   BS-A informs MS-X to hand over to BS-B.
   MS-X will change the connection from BS-A to BS-B.

### 6.2.2 Mobile Assisted Hand Over (MAHO)

The following procedure outlines the MAHO scheme.

1. Each base station can inform the connected MSs about information of the surrounding BS's including IACH information and the propagation delay between the base stations D(A,B) as described above during the ordinary connection (using control channels).
2. The mobile station can predict the IACH position of the surrounding BS's ( bandslot and timeslot ).
3. When the timeslot of the IACH occurs which the MS needs the MS will puncture both Rx and Tx traffic channels and use the idle time ( at least 4 time slots ) to pick up the target IACH.
4. The required hopping puncturing will be less than 6[%] of the data and the punctured hops

will be treated as erased bursts, the soft decision bits will be set to zero (no information). Using the proposed interleaving and coding schemes causes negligible degradation.

5. The MS activates the KERO detector active and tries to decode the IACH.
6. When the MS detects and decodes the IACH, it reports back to its own connecting BS about the successful detection of the IACH BS he detected the IACH.

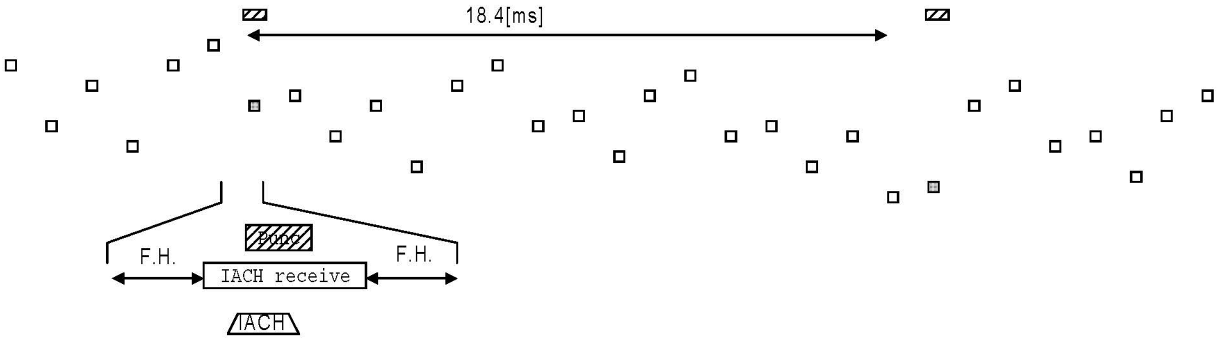



**Figure 19 Puncturing Scheme (1 of 4 Time slot usage)**

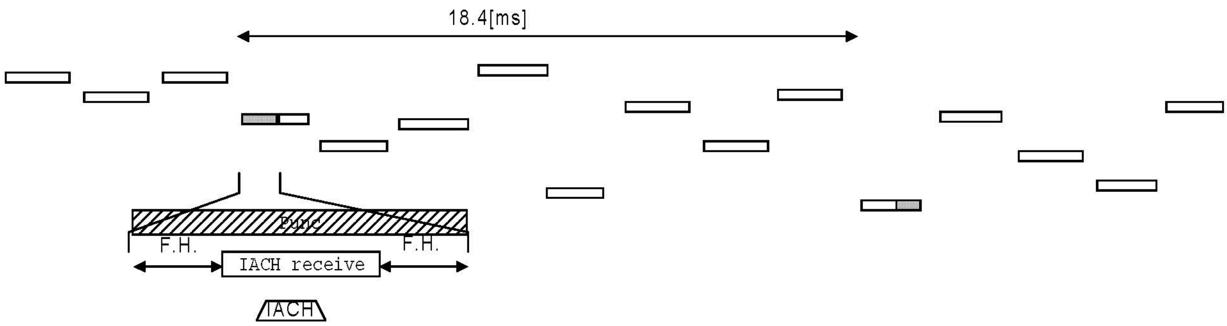



**Figure 20 Puncturing Scheme ( 7 of 8 time slot usage )**

## 6.2.3 Forward Hand Over

Forward hand over can be achieved easily.

The following description is based on the assumption that MS-X is handed over from BS-A to BS-B.

- Even after the hand over, BS-A transmits control data and dummy data instead of traffic data continuously to the receiving MS-X.
- MS will keep previous connection( BS-A ) status information such as frame timing ,hopping pattern and so on.
- If the MS fails to hand over to BS-B, it can go back to the previous connection with BS-A.
- When BS-A detect MS-X's signal again, it re-establishes the connection to MS-X.
- An alternative solution exists:
  If the network has enough capacity, The MSC can provide traffic data to BS-A also after the handover to BS-B.
  MS-X can connect to both BS's like soft handover and switch connection between both basestations based o the received signal quality.
  Another possibility in order to avoid slot puncturing is to increase the TDMA scheme during the forward handover phase (e.g. 8-TDMA ,16-TDMA) in order to prepare enough time for the hopping synthesiser to follow the two independent hopping schemes of the connected basestations.

## 6.2.4 MSC Initiated Handover

MSC initiated handover is supported even for unsynchronised base stations.
We assume the channel encoder and decoder is placed at the MSC. Each base stations has modulation and demodulation units.
The exact hand over timing is determined by the MSC and informed to both base stations and also to the target MS
The delivery of the down link data will be switched between the two base stations on a slot base (downlink hopping data) without any break (seemless).
The uplink data (slot by slot) will be gathered by the MSC.
The MS will receive and transmit continuously during hand over.
Timing adjustment will be achieved by slot puncturing.

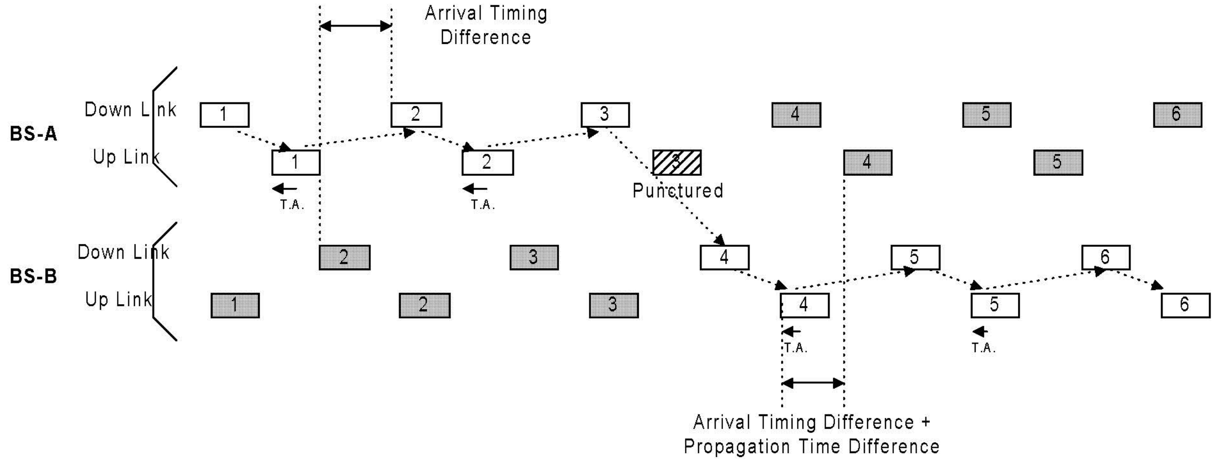



**Figure 21 MSC Puncturing Scheme**

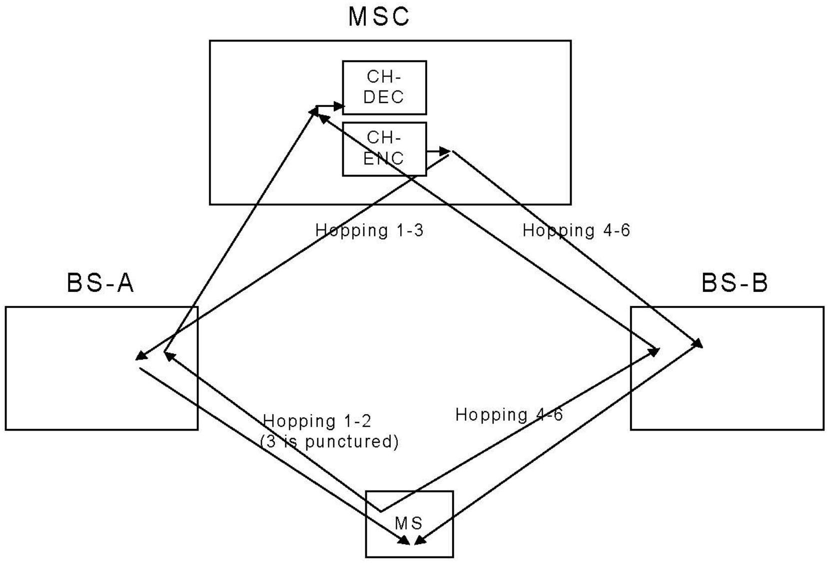



**Figure 22 MSC handover**

## 6.2.5 HCS and GSM handover

OFDMA also supports handover for the HCS cell structure and handover from the OFDMA system to the GSM system. For a HCS handover a possible handover procedure is given by,

1) Base station informs mobile station if HCS is operated in the area.
2) If HCS is operated, mobile station will mointor the different cell structures using the idle time of the TDMA scheme and hopping capability.
3) If mobile station detects different

It is very clear that a handover can easily be achieved between UMTS and GSM due to the following points:

- 288.46 µs OFDMA time slot is exactly half of the GSM time slot.
- 100 kHz channel spacing is exactly half of GSM channel spacing.
- OFDMA can handle 200 kHz bandwidth signal which is exactly same as GSM.
- Both systems are frequency hopping TDMA systems.

## 6.3 Power Control

Power control in the uplink removes the unevenness of received signal strength at the base station side and decreases the total power to the limit to support the specified QOS ( e.g. B.E.R.). At the base station the signal of each mobile station is orthogonal to all other user in the same cell, but a highly unbalanced received signal power results in interference to adjacent cells.

The accuracy is less critical than CDMA because with OFDMA orthogonality is always provided within one cell. However, a precise power control not only improves the transmission performance but also minimises the interference to other cells and therefore increases the overall capacity.

The OFDMA concept allows a variety of different power control schemes to adapt the power to the required link quality. Both closed loop and open loop power control are implemented. Based on quality parameters, measured on a slot-by-slot basis, the power is adjusted in the mobile as well as in the base station transmitter. Each receiver measures the quality of the received burst (C/I ratio) and transmits in the next burst a request to the opposite transmitter to increase, keep or decrease the power level in steps of 1dB. For the fastest power control mode one subcarrier is dedicated to carry power control information, the power is then adjusted on a frame-by-frame basis (each 1.152ms).

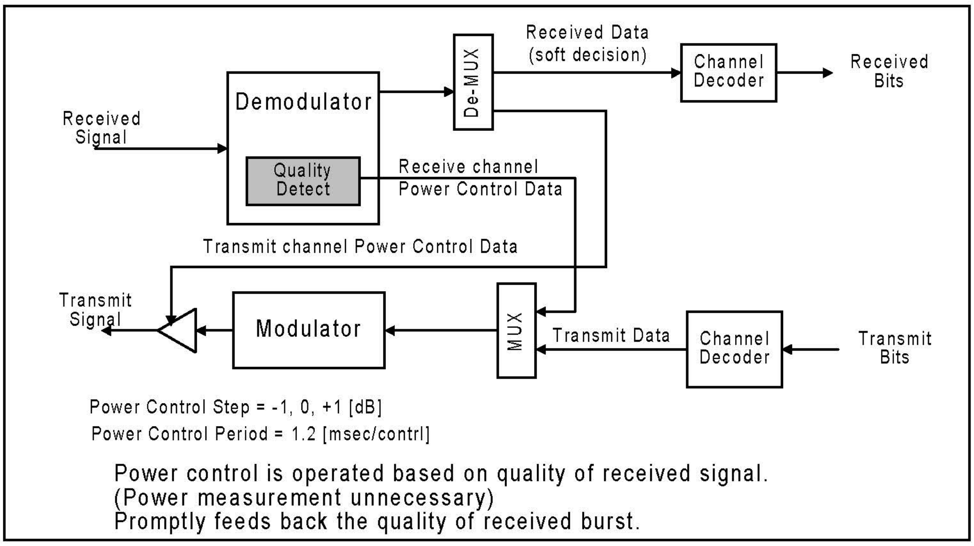



**Figure 23: Operation of Power Control**

# 7. Protocols

## 7.1 Protocol Architecture

The access control is divided into traditional sub-layers.

**Table 4: Protocol OSI Layer Structure**

| | | |
|---|---|---|
| Link Layer Control | | |
| Layer 4-7 | | |
| Layer 3 | | |
| Layer 2 | Link Layer Control (LLC) | Control for retransmission of the packet. |
| | Radio Link Control (RLC) | Divide the LLC frame into several small RLC blocks and retransmit selective parts of erroneous blocks |
| | MAC | Assign the RLC blocks on one or several TCH and handles the access to the radio media resources. |
| Layer 1 | | |

MAC layer will be separated according to each multiple access scheme described in the above section.

## 7.2 Random Frequency Hopping Operation

Frequency hopping is very effective to achieve frequency diversity and interference diversity. Frequency diversity is useful to average the frequency selective channel properties (fading dips). Interference diversity is one of the important techniques used in the OFDMA proposal and has been shown to improve capacity in slow frequency hopping TDMA systems (see *Olofsson95*).

The random hopping pattern is designed to be orthogonal within one cell (no collisions in the time-frequency grid) and random between cells (this causes co-channel interference).

The frequency hopping pattern has to fulfil certain requirements:

- Orthogonality within one cell
- Support of a variety of services by assigning different bandwidth (number of band slots)
- Support of a variety of services by assigning time slots (number of time slots)
- Support of a couple of timeslot structures (4-TDMA, 8-TDMA, 16-TDMA) within the pattern.

The hopping pattern is generated at the base station according to the expected service and traffic requirement and assigned to the cell. This assignment can be modified due to changes in the traffic characteristics. The base station can then support a set of services and a certain number of users for each service.

**Summary:**

- The random hopping pattern uses the 'frequency' resource as efficiently as possible.
- The System Guard band is extremely small compared to other systems (WB-single carrier, CDMA and traditional WB-OFDM with fixed BW).
- The hopping pattern is orthogonal within one cell (no collisions in the time-frequency grid).
- The hopping pattern supports all required services by assigning different number of band and timeslots.

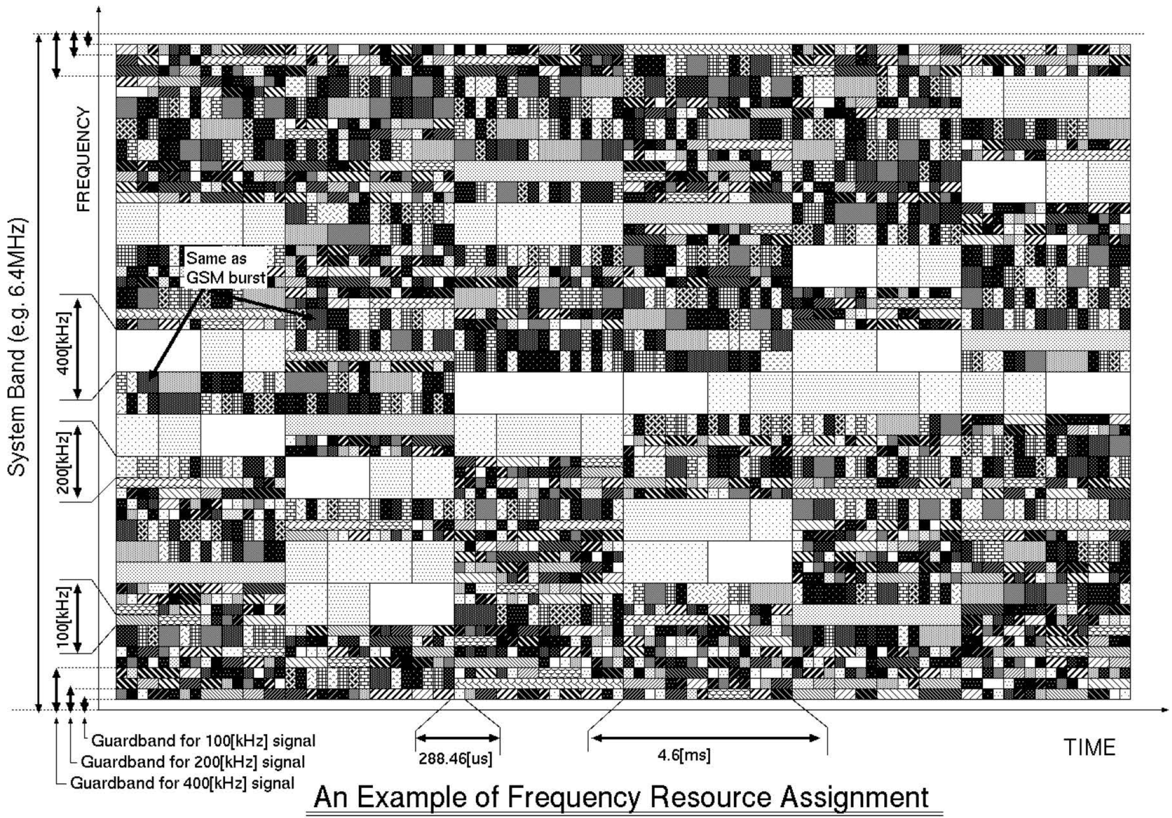



**Figure 24: Frequency Hopping Pattern**

## 7.3 Dynamic Channel Allocation (Fast DCA)

Besides FH hopping mode, the system can also be operated in Time division duplex (TDD) Mode. Unlike the FH mode, the TDD mode does not separate the spectrum in an uplink and a downlink. Instead, it assigns band slots individually to uplink or downlink connections. In TDD mode, a Dynamic Channel Allocation algorithm is employed to avoid (rather than to average) excessive interference.

The TDD mode is intended for pico-cellular, indoor use. The indoor environment is characterised by:

- Short radio propagation delays (100 m is traversed in 0.3ms, or 0.1% of the symbol duration).
- Reduced near-far effect, because of greater proximity of transmitters and receivers.
- Greater demand for high rate services, reducing the interference averaging advantage of Frequency Hopping mode.
- High speed data traffic is often asymmetric, prompting flexible division of bandwidth between uplink and downlink.
- Less severe propagation conditions than those outdoor. Mobility-induced Doppler spread and delay spread are both lower.

The Physical layer can be identical to the outdoor radio. Both coherent and differential detection can be applied. For coherent detection, dedicated indoor devices can make use of simplified channel estimation techniques (see section 6.3.1) for coherent detection, since Doppler spread is negligible.

The TDD mode of operation relies on the following principles

- In every frame, a Base Station transmits a Frame Map (FM). The Frame Map contains
    - band slot allocations for the next frame. Band slots can be allocated to
        - the base station for downlink transmission to a single terminal.
        - the base station for downlink transmission to all terminals (broadcast).
        - a single terminal for an uplink transmission.
        - all (or a group of) terminals for contention based access.
    - Transmit power assignments for MTs.
    - Acknowledgements for contention traffic received in the previous frame.
    - Slots are allocated on a connection basis, so that connection-dependent QoS can be provisioned.
    - Control data and user data are transmitted on different connections.
- Terminals can transmit requests for band slots in contention slots designated by the BS in the FM.
- Terminals can also piggyback requests onto uplink transmissions, which provides contention free access, particularly under heavy traffic conditions.
- The base station performs interference measurements in all band slots, expect at the time slots in which it is transmitting. This information is used by the band slot allocation algorithm, to assign uplink transmissions to slots with minimal interference. Note that an uplink transmission in a interference free (as measured by the BS) slot may interfere with a simultaneous uplink transmission at a neighbouring base station.
- No simultaneous uplink and downlink transmissions may be scheduled within a cell. Therefore, the blindness of the BS in slots in which it is transmitting, does not reduce capacity.
- Terminals piggyback interference measurement information onto uplink packets. In addition, the BS can query an MS to transmit interference measurement data on an uplink control channel.
- Quality monitoring of active connections is used by BSs and MSs to detect the necessity of a slot reallocation (intra-cell and inter-cell handoff).
- Synchronisation of base stations is not required. It is an option which reduces slot overlap and hence increases system capacity.
- The frame duration has a fixed value of 16 symbols, as in the mode FH channel structure. Alternative values are possible in TDD mode, but the Frame duration must be the identical for all base stations in the network.
- System bandwidth. For the indoor scenario with 30 MHz of available bandwidth, the system bandwidth can in principle be as large as 30MHz for maximal trunking gain.
- Rate ½ convolutional coding is used with up to 24 bits of user data per band slot.

**Frame Formats**

The frame layout is entirely decided by the DCA algorithm. Like the FH algorithm, the DCA algorithm is distributed and does not rely on communication via the infrastructure. Also, as the FH algorithm it is not part of the system specification, the algorithm may be vendor specific, allowing competitive positioning within a standardised system.

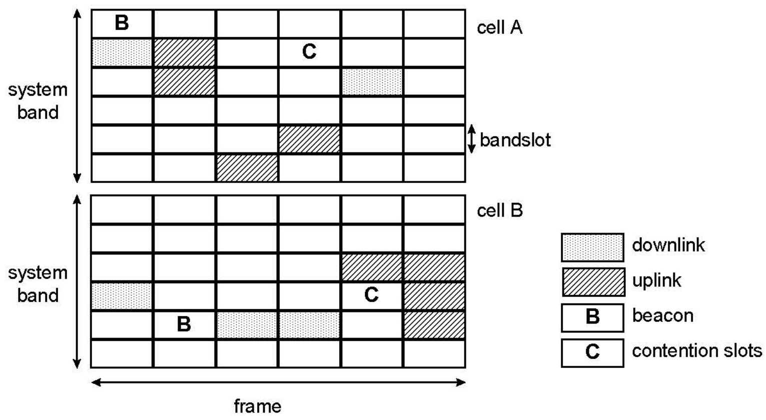



**Figure 25: Example of Frame Layout**

An example of a frame layout is shown in Figure 25. The figure is purely illustrative. The frame duration and system bandwidth have unrealistically small values. Also the packets, such as the FM and user data packets will occupy more than 1 band slot in practice.

In general the applied DCA algorithm must strive to reduce intra and inter cell interference. Constant bit rate traffic causes long term interference which is highly predictive of the interference in the next slot. If traffic is bursty, the predictive value of interference measurements is limited. Since a BS is not aware whether band slots in neighbouring cells are allocated to circuit mode or packet mode connections, BSs and MSs shall average measurements over longer periods of time. Busy slots (high average interference level) shall be avoided for any transmission. Quiet slots (low average interference) shall be assigned to constant bit rate connections, or to the guaranteed part of a variable bit rate connection. Slots with medium average interference shall be assigned to connections with bursty traffic, which use contention mode access.

Initial association does not differ from the procedure in FH mode. When joining the Base Station, the Mobile Station uses the KERO detection algorithm to detect the location of the IACH, and hence the BCCH. The BCCH is used to relay the location of the FM in the current frame to the MS. Once the FM is located it can be tracked since it will advertise when it is moved to a different location. The uplink synchronisation phase be avoided, since no timing advance is required —uplink transmissions can simply be synchronised to the downlink. The small propagation delay is easily absorbed in the symbol guard time, which is dimensioned for outdoor delay spreads.

## 7.4 Dynamic Channel Allocation ( Simple DCA )

Simple DCA assigns a fixed resource (bandslots and timeslots) to a communication during the set-up phase. This assignment is kept for the whole duration of the communication. This scheme is very simple but can not react on varying interference or channel conditions compared to fast DCA where the ‘actual best’ channel (= timeslot & bandslot combination) is used for transmission. This scheme has a lower performance than the fast DCA operation but can be used for simple (uncoordinated) systems like cordless telephony.

[For Further Study]

# 8. System Deployment Aspects

## 8.1 System Guard

The multirate concept of the OFDMA is the assignment of multiple time-slots and multiple band-slots. Wide band signals in any system have the disadvantage of the requirement for a wider guard band. This is a limiting factor for every system using wide band signals. The system guard band depends on the spectrum mask to separate different systems. With a wide band signal a larger system guard band has to be prepared compared to narrow band systems.
This considerations are also valid for OFDMA. To reduce this overhead frequency hopping patterns were developed which avoid the allocation of wideband signals close to the edge of the system band. Narrow band signals (e.g. voice, low-rate data) can be positioned close to the edge of the system band. This gives an additional increment of the system resources usage.
A system using only wide-band carriers has to have a much larger guard band (reduced efficiency of the systems resource allocation).

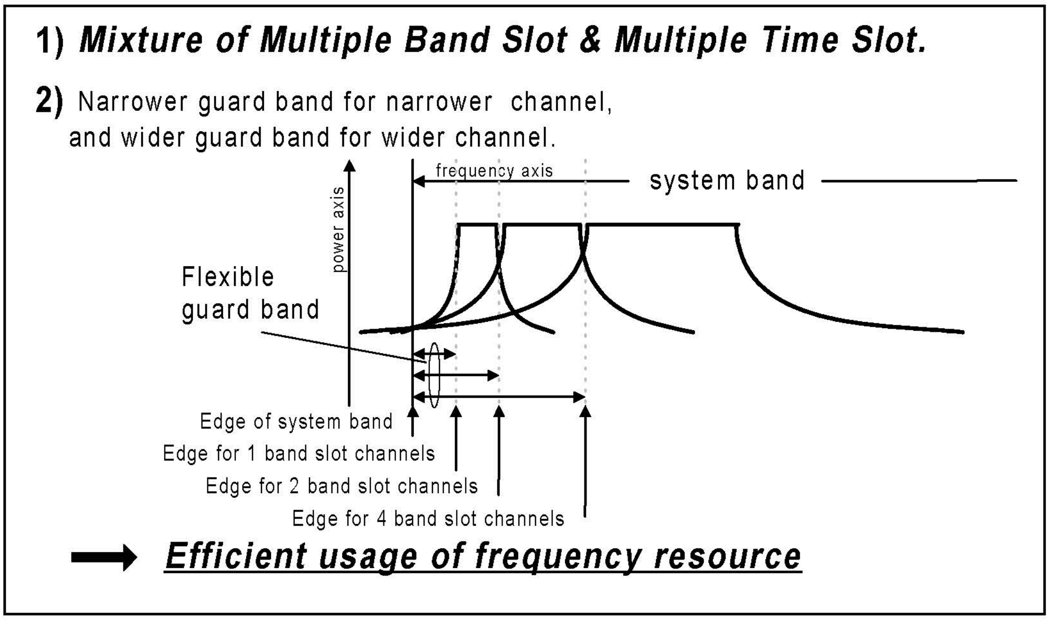



**Figure 26: Flexible OFDMA Structure**

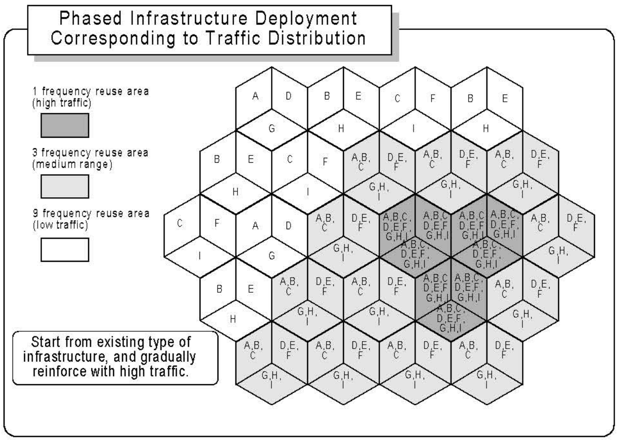
## 8.2 Phased Deployment Model

A phased introduction is very effective to reduce the roll-out cost of the UMTS system. Starting with deployment scenarios to support the initial low density penetration of UMTS the system can be extended in steps according to the demanded traffic.

An example:

- Initial stage:
  9-Frequency reuse, which is the same as used in current GSM system has a large margin of CIR and link budget. The OFDMA system supports as much as possible the backwards compatibility to GSM including aspects of the air-interface. Therefore the investment and resources used in the GSM system can be re-used.

- Second stage:
  When the penetration of UMTS subscribers increases, a reduction of the reuse factor to 3 is possible which still has some margin for stable and safe operation.
- Third stage:
  When traffic grows in very high traffic areas, 1 frequency reuse operation will be implemented. Enhanced infrastructure will be needed, but only in high traffic areas.




In the case of a CDMA system, 1-frequency reuse operation and soft hand over is a mandatory requirement even in the introduction phase of UMTS or very low traffic density area. This increases initial investments and operating costs compared to OFDMA.

## 8.3 Commonality Aspects

Commonality is an important high level requirement for UMTS.
Commonality means the support of cellular (co-ordinated systems) and also cordless (uncoordinated systems) communication with the same terminal. The OFDMA system can efficiently support all operating environments including uncoordinated systems (like cordless telephony). Another aspect of commonality is the operation in different radio environments. The OFDMA system can operate in any radio propagation environment (pico cells, micro cells, macro cells) and can easily support hierarchical cell structures without modifications of the burst structure.
The support of various data-rates required for UMTS (up to 2Mbps) is also very important. The supported data-rate depends on the number of allocated time and bandslots for one communication link. Different classes of terminals can therefore be defined providing the end user with a cost efficient solution. These classes could include a very cheap low-end terminals (e.g. supporting speech and data services up to 64kbps) a medium terminal (up to 384kbps) and a high-end terminal (up to 2Mbps).

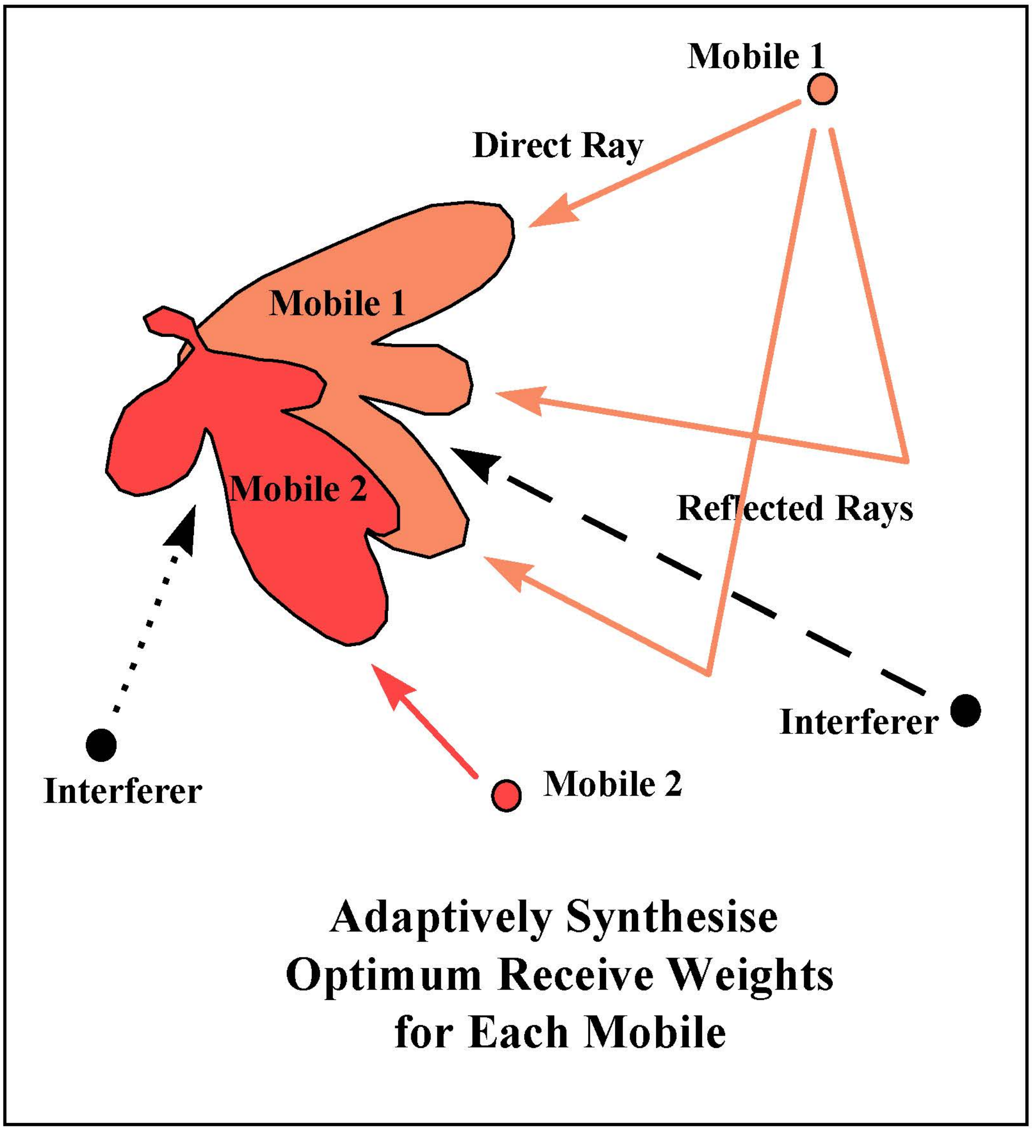
## 8.4 Deployment Options

The OFDMA proposal offers operators and users a full range of deployment options.
For traditional licensed outdoor cellular operation, including the improved UMTS higher bit rate services, OFDMA offers the Random Slow frequency Hopping MAC (see section 7.2). This MAC can be configured to eliminate the need for deliberate frequency planning (effective frequency re-use pattern of 1) if required and still provide performance(in terms of user capacity) comparable to other technologies. In addition, traditional TDMA system cellular system planning and enhancement techniques, such as cell sectorisation, hierarchical cell structures and adaptive/smart antennas (see section 8.5) can be applied to dramatically boost capacity further.
For unlicensed usage and use in allocations of unpaired spectrum, i.e. in indoor office WLAN style environments, the OFDMA DCA-TDD MAC option (see section 7.3) would be applied. This is being especially developed to impose no restrictions on adjacent base stations physical locations or synchronisation and to allow truly asymmetrical services.
Having a modulation scheme based on narrowband OFDM sub-carriers, provides this proposal with a degree of freedom in the frequency domain that other proposals cannot match. For instance, for the SFH MAC option, if an operator requires a more capacity on the downlink than the uplink, then it is possible to increase or decrease either the uplink or downlink spectrum allocation in increments of one bandslot (100kHz) down due a minimum bandwidth per link of 800 kHz (with a modified BCCH channel). This capability to accommodate OFDMA within relatively narrow portions of spectrum, is advantageous to operators who desire asymmetric capacity between their up and down links and also to

operators who wish to re-farm existing frequency allocations to this technology.

## 8.5 Adaptive/Smart Antenna

Adaptive antennas reduce the amount of co-channel interference, enabling operators to employ tighter frequency re-use thus increasing the network capacity. Conservative estimates suggest that an existing system designed with a frequency re-use plan of 4/3 could have its frequency plan tightened to 1/3 giving a potential factor of two improvement in capacity.
Interference reduction is achieved by using the principle of spatial filtering. Complex algorithms are used to adapt the antenna radiation pattern in order to maximise the signal-to-interference-and-noise (SINR) ratio and doing so "nulls" are created in the direction of interfering signals. This adaptation is performed on a per timeslot (or bandslot) basis (see figure below). The base station is able to constructively combine the multipath signals from the wanted mobile while "nulling out" those signals originating from interfering mobiles.



# 9. Simulation Description

Performance evaluation of the OFDMA concept group has been carried out by simulation according to ETR-0402. The following simulation scenarios were considered during the first phase of simulations.

The two operational styles of the OFMDA proposal (using SFH and differential detection or coherent reception in combination with DCA) have been analysed.

For the first operation style (differential reception and SFH) the following scenarios were simulated.

| Environment | Propagation Model | Service Mixture | Cell Type | Link Level | System Level |
|---|---|---|---|---|---|
| Vehicular 120km/h | Vehicular A | UDD 144<br>Speech<br>LCD 144<br>LCD 384 | Macro | Yes<br>Yes<br>Yes<br>Yes | No<br>Yes<br>No<br>Yes |
| Outdoor to Indoor and Pedestrian 3km/h | Outdoor to Indoor and Pedestrian A | UDD 384<br>Speech<br>LCD 144<br>UDD 2048 | Micro | Yes<br>Yes<br>Yes<br>Yes | Yes<br>Yes<br>No<br>No |
| Indoor Office 3km/h | Indoor Office A | UDD 2048<br>Speech<br>LCD 384<br>50% speech + 50% UDD 384 | Pico | Yes<br>Yes<br>Yes<br>No | Yes<br>Yes<br>No<br>No |

For the second operation style (coherent reception) the following scenarios were simulated.

| Environment | Propagation Model | Service Mixture | Cell Type | Link Level | System Level |
|---|---|---|---|---|---|
| Indoor Office 3km/h | Indoor Office A | | Pico | Yes | No |

## 9.1 Link Level Simulation Description (Differential Operation)

The required $E_B/N_0$ figures presented here represent the values needed in the receiver to support the corresponding BER values including all necessary overheads (control channels, PC information). Energy from common broadcast channels are not included.
Both uplink and downlink assume antenna diversity. Eb/No values are all ratio of a bit energy ( Eb[J/bit] ) which is actually fed into the receiver versus noise density (No[J] ) without power control at transmitter side.

### 9.1.1 Speech Services

The speech service simulations assume a hypothetical 8kbps speech codec with a user BER requirement of $10^{-3}$. Interleaving is achieved over 4 GSM frames (18.48ms) which satisfies the UMTS requirements of one-way delay below 20ms. Larger inter-frame interleaving can be applied if the delay constraints are relaxed, this improves performance especially in low speed scenarios. A convolutional code of rate 1/3 and constraint length of 7 was used for up and downlink. The Modulation scheme is (FD)DQPSK. The implementation of the CC does not require tail bits.

Speech channel (User data): 148 bits (per 18.46ms), 16 CRC bits (per 18.46ms).
(Control): 16 PC bits(per 18.46ms), 49 general (per 18.46ms)

### 9.1.2 LCD Services

The required BER can be achieved using concatenated codes. Interleaving is achieved over 8 frames (interleaver delay 8*18.46ms=147ms). The outer code is a Reed-Solomon code with a small size and efficient coding rate considering actual implementation. RS code parameters are: GF(255), (n,k) = (40,36) or (80,72) ( R = 0.9 ). The RS interleaver length is 144ms.
The 'user' satisfaction' criteria are according to 0402, which includes blocking, quality and dropping.
The quality threshold is a BER of $10^{-6}$ for 95% of the time. Dropping will occur if the duration of a BER > $10^{-6}$ is longer than 26s for LCD 384.

- LCD 144:
  Time slot usage is 7 of 8 time slots and remaining 1 slot if for frequency hopping. 4 band slots (400[kHz] BW) are used.
  Modulation scheme is (FD)DQPSK
  Convolutional coding rate is R = 1/3
  Link level bit rate is a little bit too high ( 163[kbps] ) which can be modified to 144[kbps] by repetition.
- LCD 384
  Time slot usage is 7 of 8 time slots and remaining 1 slot if for frequency hopping.
  8 band slots ( 800[kHz] BW ) are used.
  Modulation scheme is (FD)DQPSK
  Convolutional coding rate is approximately R = 1/2.5 by puncturing technique to match the 384[kbps]

### 9.1.3 UDD Services

UDD144, UDD384 and UDD2048 link level simulations have been performed according to ETR0402.

## 9.2 Link Level Simulation Description (Coherent Operation)

Indoor link level simulations were performed for packets of 14400 bits (6 blocks of 4 symbols for coherent, 24 symbols for differential). No antenna diversity was used. Bit and packet error ratios were obtained by averaging over 1000 independent channels. QPSK with rate ½ coding was used (constraint length 7).
The BER versus $E_b/N_o$ figures are derived with and without power control. Using power control the results show 10 dB better values compared to the average required $E_b/N_o$ in the case of no power control (at BER of $10^{-3}$ ).

## 9.3 System Level Simulation Description (Differential Operation)

The simulations were carried out according to the system deployment scenarios, mobility models and user satisfaction criteria's of ETR-0402.

### 9.3.1 Speech Services

For speech (circuit switched service), the performance has been evaluated have been evaluated using dynamic system simulations. Speech is considered using 50% voice activity.

### 9.3.2 LCD Services

Circuit switched LCD services have been evaluated using dynamic system simulations.
The 'user' satisfaction' criteria are according to 0402, which includes blocking, quality and dropping.
The quality threshold is a BER of $10^{-6}$ for 95% of the time. Dropping will occur if the duration of a BER > $10^{-6}$ is longer than 26s for LCD 384.

### 9.3.3 UDD Services

UDD services were simulated according to 0402. The 'user' satisfaction criteria is set according to the latest definition contained in document SMG G18/97. This stipulates that the throughput of a satisfied user is 10% of the average bit rate stated in 0402. No user are dropped during the duration of the call.

# 10. Link Level Results (Differential Operation)

In this section link level results are presented using the channel characteristics given in the 0402 document. Eb/No values are all ratio of a bit energy (Eb[J/bit] )which is actually fed into the receiver versus noise density (No[J] ) without power control at transmitter side. All link level simulations apply antenna diversity (2 antennas) with frequency hopping around 12.8MHz.

## 10.1 Speech

The simulation parameters for speech are shown in Table 5. The BER results are shown in Figure 27. The $E_b/N_0$ values presented in Figure 27 include all the overheads needed for control channels.

**Table 5 - Simulation parameters for speech**

| Environment | (O) | (P) | (V) |
|---|---|---|---|
| Delay profile | Office A | Pedestrian A | Vehicular A |
| Mobile speed | 3[km/h] | 3[km/h] | 120[km/h] |
| UL/DL | both | both | both |
| Antenna diversity | 2 branches | 2 branches | 2 branches |
| Link level bit rate [kbps] | 12.1[kbps] | 12.1[kbps] | 12.1[kbps] |
| Information bit rate [kbps] | 8[kbps] | 8[kbps] | 8[kbps] |
| Modulation | FDDQPSK | FDDQPSK | FDDQPSK |
| Convolutional coding | K = 7, R = 1/3 | K = 7, R = 1/3 | K = 7, R = 1/3 |
| Interleaver length (CC) | 18.4[ms](16hop) | 18.4[ms](16hop) | 18.4[ms](16hop) |
| RS coding | No | No | No |
| Interleaver length (RS) | N/A | N/A | N/A |
| Time slot usage | 1(1/4) | 1(1/4) | 1(1/4) |
| Band slot usage | 1(100[kHz]) | 1(100[kHz]) | 1(100[kHz]) |
| Frequency hopping bandwidth | 12.8[MHz] | 12.8[MHz] | 12.8[MHz] |
| Power Control | No | No | No |
| Required. Average .received Eb/No[dB] @BER=10^(-3) | 10.0[dB] | 11.2[dB] | 5.6[dB] |

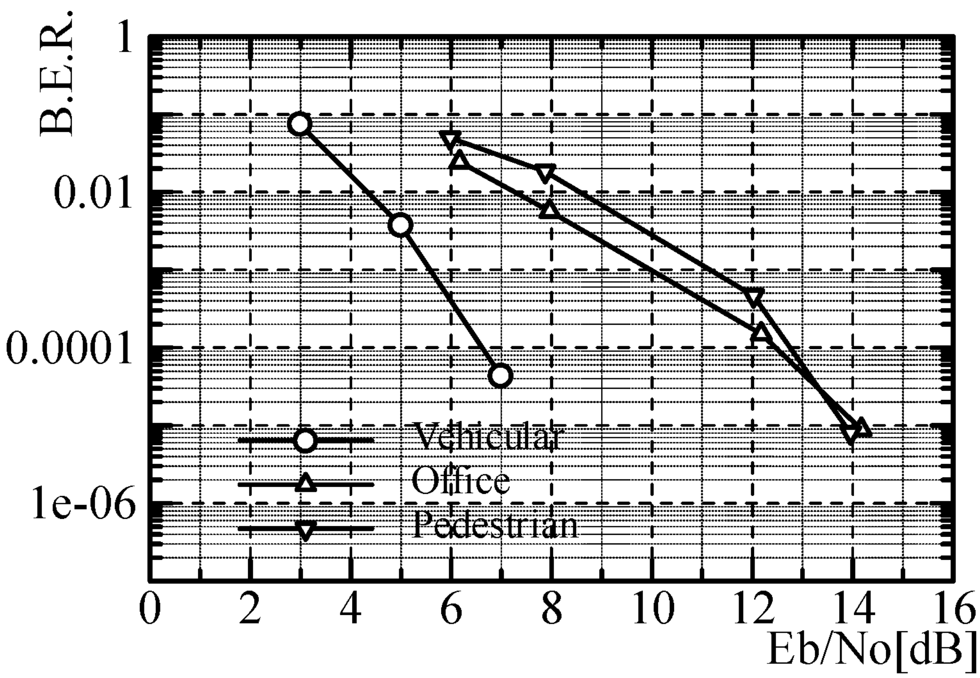



**Figure 27: Eb/No vs BER (SPEECH)**

## 10.2 LCD 144 Simulation

The simulation parameters for LCD 144 are shown in Table 6. In order to achieve the low bit error rates required RS error coding is applied. The details of the RS coding is shown in Table 6. The BER results are shown in Figure 28.

**Table 6: Simulation parameters for LCD 144**

| Environment | (O) | (P) | (V) |
|---|---|---|---|
| Delay profile | Office A | Pedestrian A | Vehicular A |
| Mobile speed | 3[km/h] | 3[km/h] | 120[km/h] |
| UL/DL | both | both | both |
| Antenna diversity | 2 branches | 2 branches | 2 branches |
| Link level bit rate [kbps] | 163[kbps] | 163[kbps] | 163[kbps] |
| Information bit rate [kbps] | 144[kbps] | 144[kbps] | 144[kbps] |
| Modulation | FDDQPSK | FDDQPSK | FDDQPSK |
| Convolutional coding | K = 7, R = 1/3 | K = 7, R = 1/3 | K = 7, R = 1/3 |
| Interleaver length (CC) | 147.2[ms] (64hop) | 147.2[ms] (64hop) | 147.2[ms] (64hop) |
| RS coding | GF(255)(40,36) | GF(255)(40,36) | GF(255)(40,36) |
| Interleaver length (RS) | 144[ms] | 144[ms] | 144[ms] |
| Time slot usage | 7(7/8) | 7(7/8) | 7(7/8) |
| Band slot usage | 4(400[kHz]) | 4(400[kHz]) | 4(400[kHz]) |
| Frequency hopping bandwidth | 12.8[MHz] | 12.8[MHz] | 12.8[MHz] |
| Power control | No | No | No |
| Required. Average .received Eb/No[dB] @BER=10^(-6) | | 10.0[dB] | 5.9[dB] |

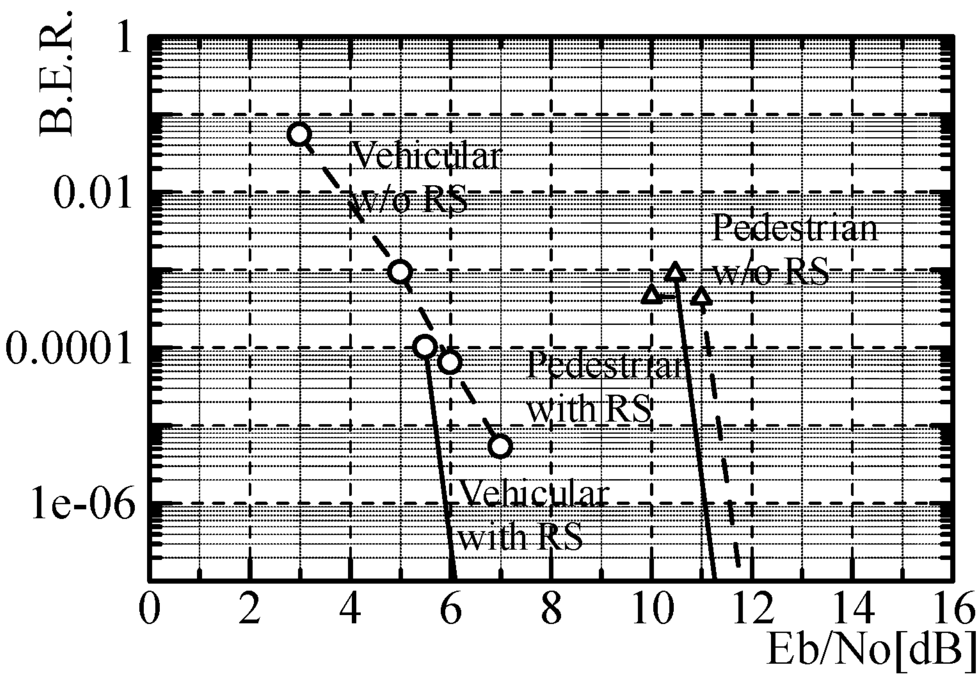



**Figure 28: Eb/No vs BER (LCD 144)**

## 10.3 LCD 384 Simulation

The simulation parameters for LCD 384 are shown in Table 7. In order to achieve the low bit error rates required RS error coding is applied. The details of the RS coding is shown in Table 7. The BER results are shown in Figure 29.

**Table 7: Link Level Simulation parameters for LCD 384**

| Environment | (O) | (P) | (V) |
|---|---|---|---|
| Delay profile | Office A | Pedestrian A | Vehicular A |
| Mobile speed | 3[km/h] | 3[km/h] | 120[km/h] |
| UL/DL | both | both | both |
| Antenna diversity | 2 branches | 2 branches | 2 branches |
| Link level bit rate [kbps] | 396[kbps] | 396[kbps] | 396[kbps] |
| Information bit rate [kbps] | 384[kbps] | 384[kbps] | 384[kbps] |
| Modulation | FDDQPSK | FDDQPSK | FDDQPSK |
| Convolutional coding | K = 7, R = 1/2.5 | K = 7, R = 1/2.5 | K = 7, R = 1/2.5 |
| Interleaver length (CC) | 147.2[ms] (64hop) | 147.2[ms] (64hop) | 147.2[ms] (64hop) |
| RS Coding | GF(255)(40,36) | GF(255)(40,36) | GF(255)(80,72) |
| Interleaver length (RS) | 144[ms] | 144[ms] | 144[ms] |
| Time slot usage | 7(7/8) | 7(7/8) | 7(7/8) |
| Band slot usage | 8(800[kHz]) | 8(800[kHz]) | 8(800[kHz]) |
| Frequency hopping bandwidth | 12.8[MHz] | 12.8[MHz] | 12.8[MHz] |
| Power control | No | No | No |
| Required. Average .received Eb/No[dB] @BER=10^(-6) | 11.3[dB] | | 5.8[dB] |

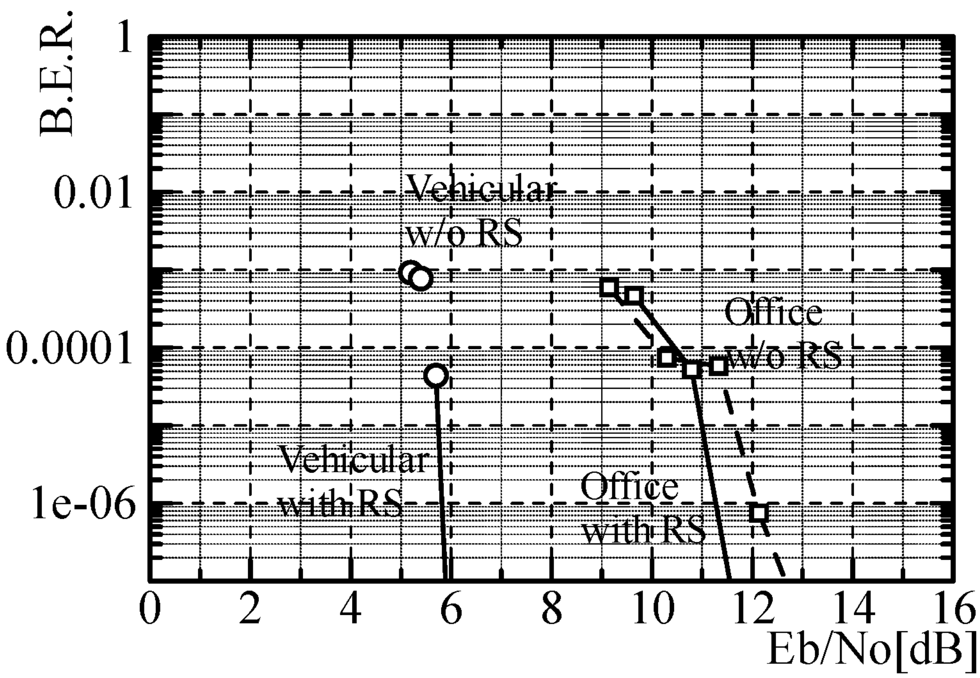



Figure 29: Eb/No vs BER (LCD384)

## 10.4 UDD 144, 384 Link Level Simulation

For implementing UDD services two modes were investigated. The first of these, mode A, is an LCD type interleaving coding method which uses an interleaver depth of 16. CRC bits are then added to the packet. No RS coding is used. The parameters of Mode A are seen in Table 8 and Table 9.

Mode B uses a block coding method in which each packet contains both CRC and RS code bits. The parameters of Mode A are seen in Table 10.

### 10.4.1 Mode A

Table 8: Simulation parameters for UUD384 Mode A

| Environment | (O) | (P) | (V) |
|---|---|---|---|
| Delay profile | Office A | Pedestrian A | Vehicular A |
| Mobile speed | 3[km/h] | 3[km/h] | 120[km/h] |
| UL/DL | both | both | both |
| Antenna diversity | 2 branches | 2 branches | 2 branches |
| Link level bit rate [kbps] | 1.27[Mbps] | 1.27[Mbps] | 1.27[Mbps] |
| Information bit rate [kbps] | 416[kbps] | 416[kbps] | 416[kbps] |
| Modulation | FDDQPSK | FDDQPSK | FDDQPSK |
| Convolutional coding | K = 7, R = 1/3 | K = 7, R = 1/3 | K = 7, R = 1/3 |
| Interleaver length (CC) | 18.4[ms] (16hop) | 18.4[ms] (16hop) | 18.4[ms] (16hop) |
| Data block | 320[bits] | 320[bits] | 320[bits] |
| CRC | 16[bits] | 16[bits] | 16[bits] |
| RS coding | N/A | N/A | N/A |
| Interleaver length (RS) | N/A | N/A | N/A |

| | | | |
|---|---|---|---|
| Time slot usage | 3(3/4) | 3(3/4) | 3(3/4) |
| Band slot usage | 8(800[kHz]) | 8(800[kHz]) | 8(800[kHz]) |
| Frequency hopping bandwidth | 12.8[MHz] | 12.8[MHz] | 12.8[MHz] |
| Power control | No | No | No |
| Required. Average .received Eb/No[dB] @BLER=10^(-1) | 7.0[dB] | 7.8[dB] | 5.2[dB] |

### Table 9: Simulation parameters for UUD144 Mode A

| Environment | (O) | (P) | (V) |
|---|---|---|---|
| Delay profile | Office A | Pedestrian A | Vehicular A |
| Mobile speed | 3[km/h] | 3[km/h] | 120[km/h] |
| UL/DL | both | both | both |
| Antenna diversity | 2 branches | 2 branches | 2 branches |
| Link level bit rate [kbps] | 637[kbps] | 637[kbps] | 637[kbps] |
| Information bit rate [kbps] | 208[kbps] | 208[kbps] | 208[kbps] |
| Modulation | FDDQPSK | FDDQPSK | FDDQPSK |
| Convolutional coding | K = 7, R = 1/3 | K = 7, R = 1/3 | K = 7, R = 1/3 |
| Interleaver length (CC) | 18.4[ms] (16hop) | 18.4[ms] (16hop) | 18.4[ms] (16hop) |
| Data block | 320[bits] | 320[bits] | 320[bits] |
| CRC | 16[bits] | 16[bits] | 16[bits] |
| RS coding | N/A | N/A | N/A |
| Interleaver length (RS) | N/A | N/A | N/A |
| Time slot usage | 3(3/4) | 3(3/4) | 3(3/4) |
| Band slot usage | 4(400[kHz]) | 4(400[kHz]) | 4(400[kHz]) |
| Frequency hopping bandwidth | 12.8[MHz] | 12.8[MHz] | 12.8[MHz] |
| Power control | No | No | No |
| Required. Average .received Eb/No[dB] @BLER=10^(-1) | 7.0[dB] | 7.8[dB] | 5.2[dB] |

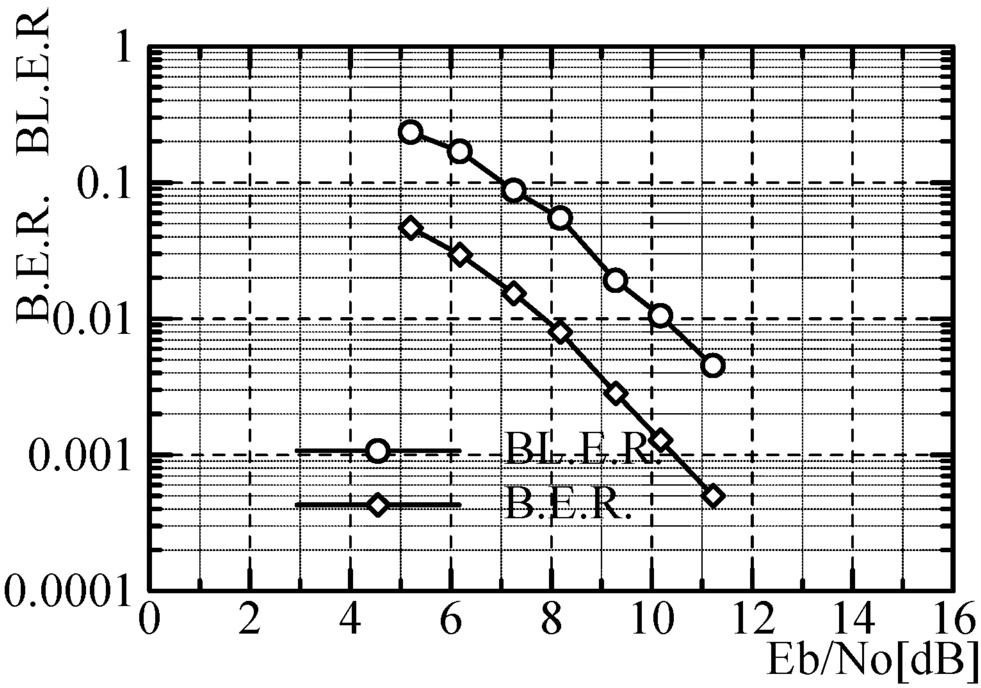



**Figure 30 Eb/No vs BL.E.R. ( Mode A, Office)**

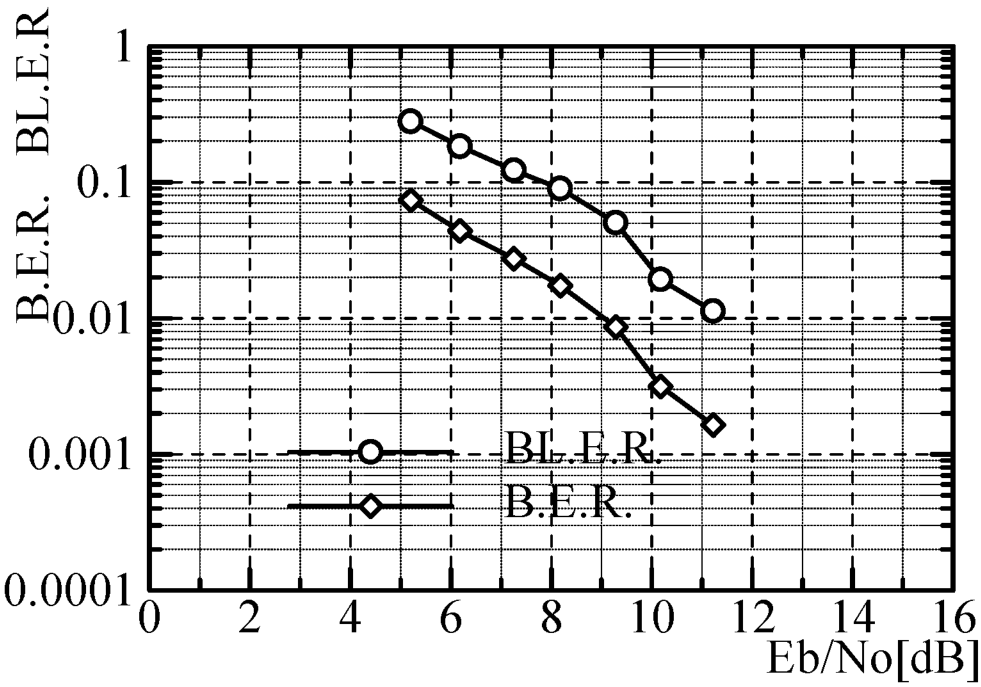



**Figure 31 Eb/No vs BL.E.R. ( Mode A, Pedestrian)**

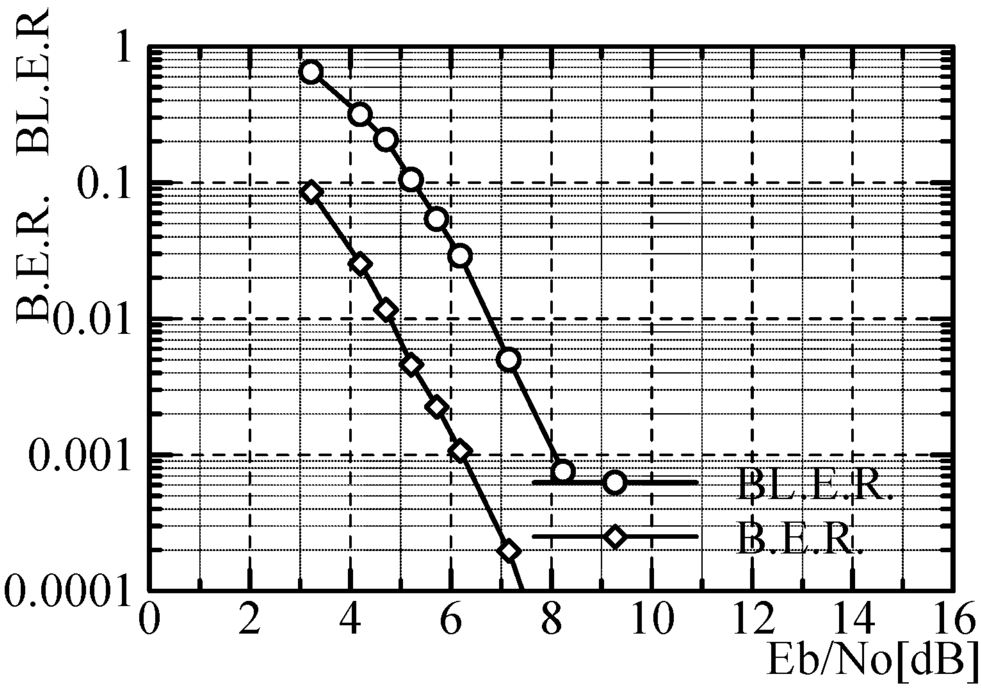



**Figure 32 Eb/No vs BL.E.R. ( Mode A, Vehicular)**

### 10.4.2 Mode B

**Table 10: Simulation parameters for UUD384 Mode B**

| Environment | (O) | (P) | (V) |
|---|---|---|---|
| Delay profile | Office A | Pedestrian A | Vehicular A |
| Mobile speed | 3[km/h] | 3[km/h] | 120[km/h] |
| UL/DL | both | both | both |
| Antenna diversity | 2 branches | 2 branches | 2 branches |
| Link level bit rate [kbps] | 637[kbps] | 637[kbps] | 637[kbps] |
| Information bit rate [kbps] | 416[kbps] | 416[kbps] | 416[kbps] |
| Modulation | FDDQPSK | FDDQPSK | FDDQPSK |
| Convolutional coding | K = 7, R = 1/2 | K = 7, R = 1/2 | K = 7, R = 1/2 |
| Interleaver length (CC) | 1.15[ms] | 1.15[ms] | 1.15[ms] |
| Data block | 480[bits] | 480[bits] | 480[bits] |
| CRC | 16[bits] | 16[bits] | 16[bits] |
| RS coding | N/A | N/A | N/A |
| Interleaver length (RS) | N/A | N/A | N/A |
| Time slot usage | 4 | 4 | 4 |
| Band slot usage | 4(400[kHz]) | 4(400[kHz]) | 4(400[kHz]) |
| Frequency hopping bandwidth | No FH | No FH | No FH |
| Power control | No | No | No |
| Required. Average .received Eb/No[dB] @BER=10^(-1) | 7.8[dB] | 8.5[dB] | 8.8[dB] |

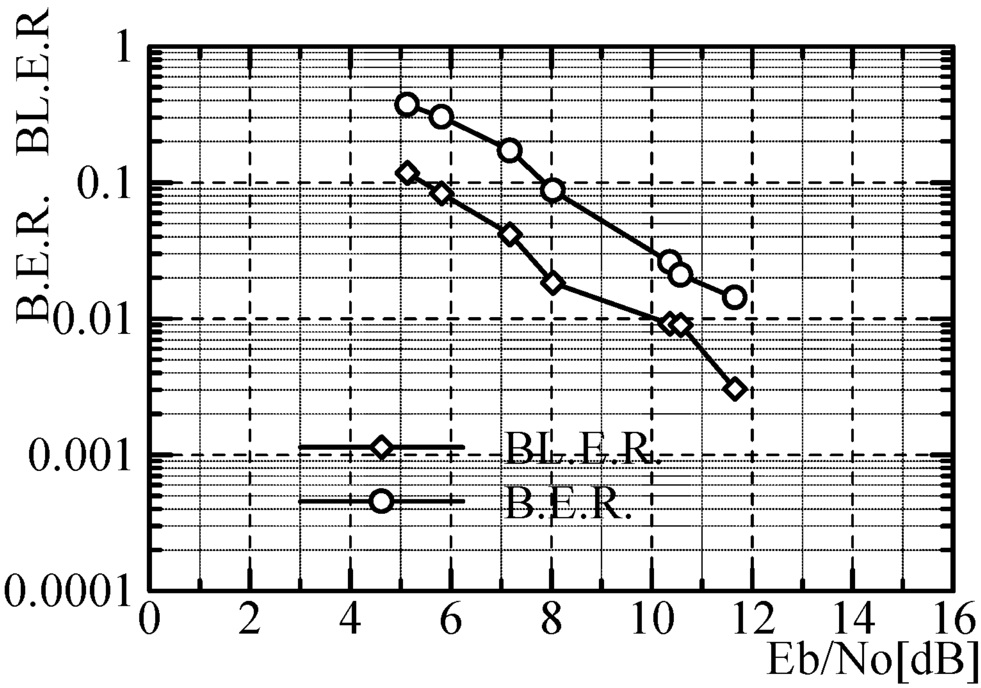



**Figure 33 Eb/No vs BL.E.R. ( Mode B, Office)**

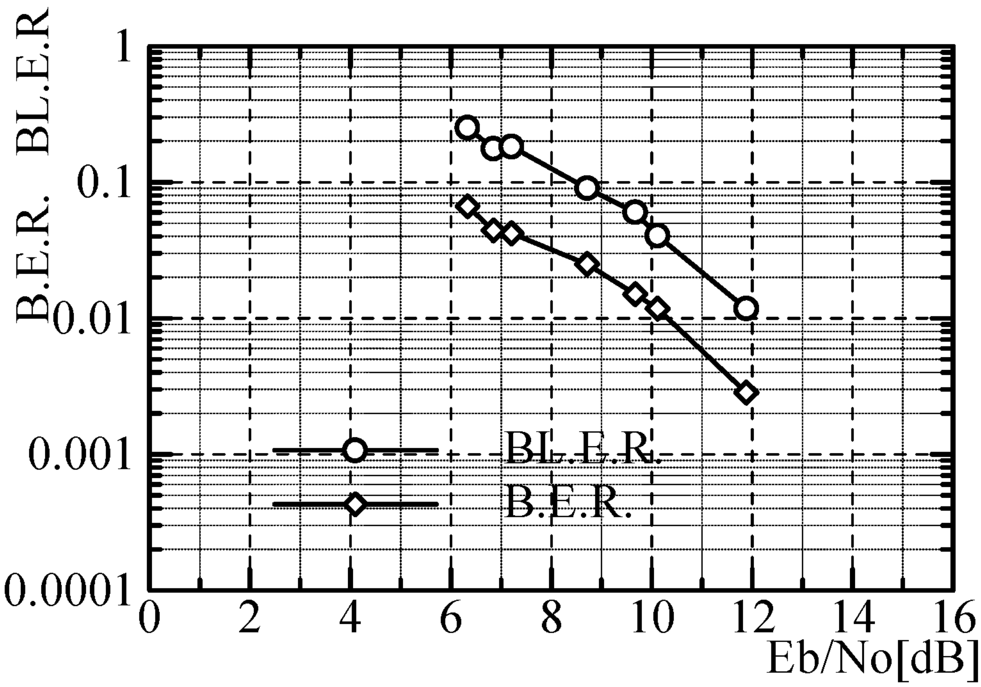



**Figure 34 ( Mode B, Office)**

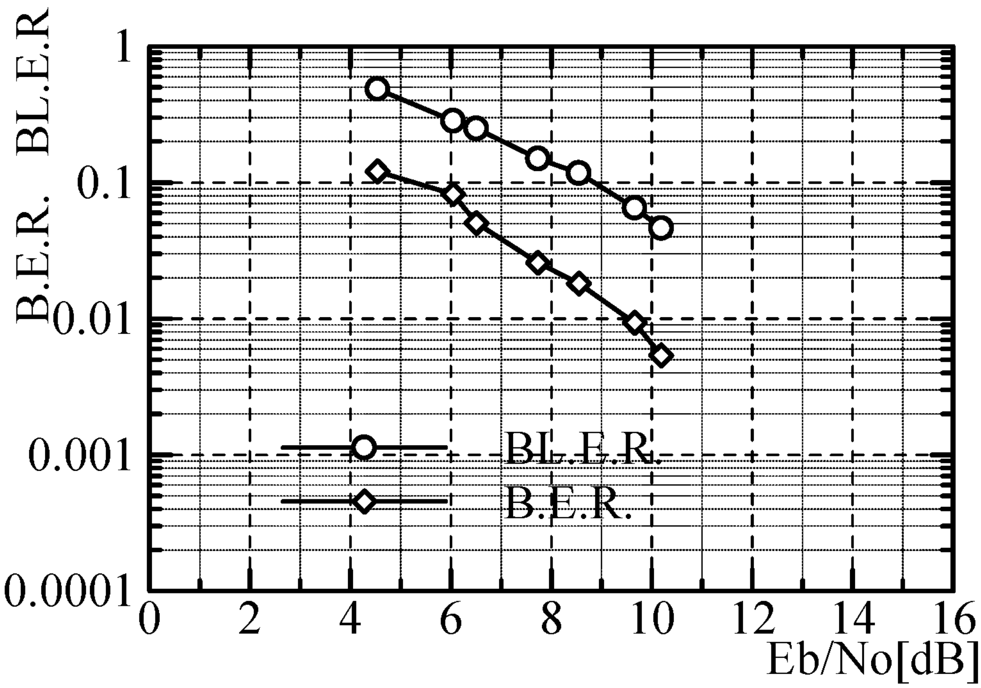



**Figure 35 Eb/No vs BL.E.R. ( Mode B, Vehicular)**

## 10.5 UDD 2048 Simulation

### 10.5.1 Mode B

**Table 11: Simulation parameters for UUD2048 Mode B**

| Environment | (O) | (P) |
|---|---|---|
| Delay profile | Office A | Pedestrian A |
| Mobile speed | 3[km/h] | 3[km/h] |
| UL/DL | both | both |
| Antenna diversity | 2 branches | 2 branches |
| Link level bit rate [kbps] | 3.82[Mbps] | 3.82[Mbps] |
| Information bit rate [kbps] | 2.218[Mbps] | 2.218[Mbps] |
| Modulation | FDD8PSK | FDD8PSK |
| Convolutional coding | K = 7, R = 1/2 | K = 7, R = ½ |
| Interleaver length (CC) | 288[us] | 288[us] |
| Data block | 320[bits] | 320[bits] |
| CRC | 16[bits] | 16[bits] |
| RS coding | N/A | N/A |
| Interleaver length (RS) | N/A | N/A |
| Time slot usage | 2 blocks per Time Slot | 2 blocks per Time Slot |
| Band slot usage | 16(1.6[MHz]) | 16(1.6[MHz]) |
| Frequency hopping bandwidth | No FH | No FH |
| Power control | No | No |
| Required. Average .received Eb/No[dB] @BER=10^(-1) | 10.3[dB] | 10.3[dB] |

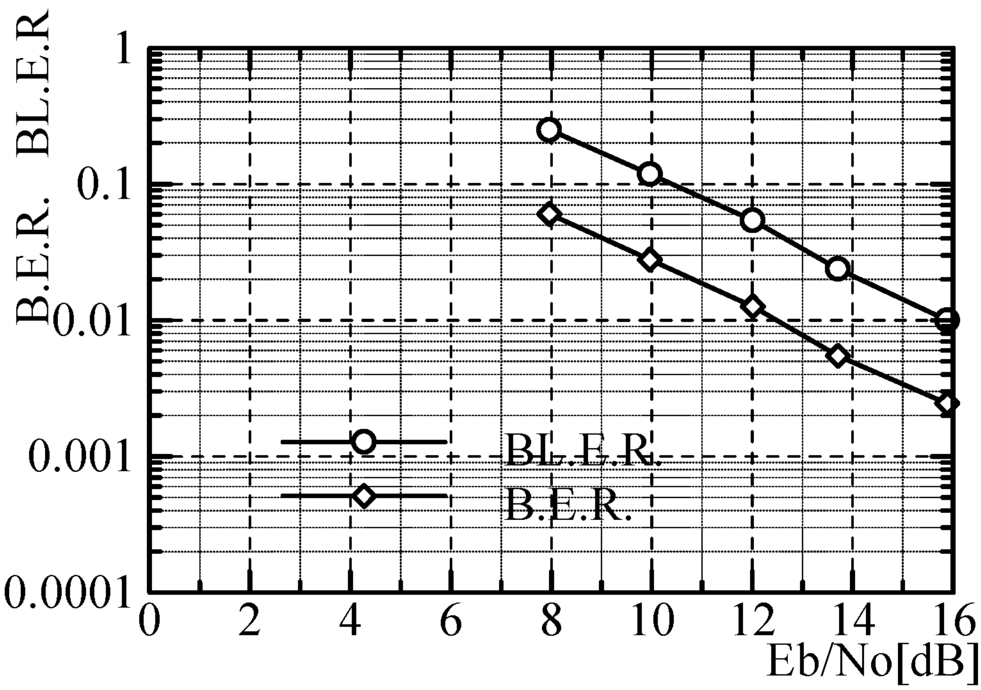



**Figure 36 Eb/No vs BL.E.R. ( UUD2048, Office )**

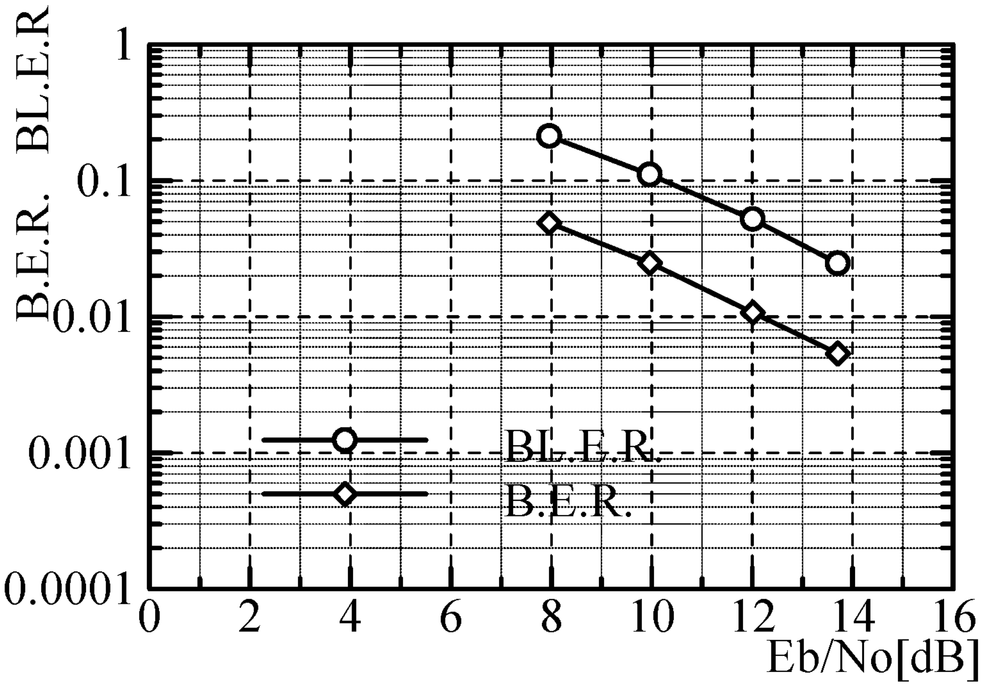



Figure 37 Eb/No vs BL.E.R. (UUD2048, Pedestrian)

# 11. Link Level Results (Coherent Operation)

For the coherent operation mode the Indoor scenario was considered first.
Indoor link level simulations were performed for packets of 14400 bits (6 blocks of 4 symbols for coherent, 24 symbols for differential). No antenna diversity was used. Bit and packet error ratios were obtained by averaging over 1000 independent channels, according to the indoor model A. For the highest data rate, each OFDM symbol has 600 subcarriers, so the data rate is 2.08 Mbps. The total number of subcarriers is 3600 in a bandwidth of 15 MHz. QPSK with rate ½ coding was used (constraint length 7).

Figure 38 shows bit and packet error ratios versus $E_b/N_o$ without power control. Figure 39 shows the same results with power control. In this case, the results are much better because $E_b/N_o$ is now constant for each packet. For a BER of $10^{-3}$, for instance, about 5.5 dB $E_b/N_o$ is required for coherent detection, which is about 10 dB better than the average required $E_b/N_o$ in the case of no power control. However, it should be noted that this improvement holds for the mean $E_b/N_o$ at the input of the receiver. $E_b/N_o$ does not include any increase in the average transmit power, which will be present in the case of power control.

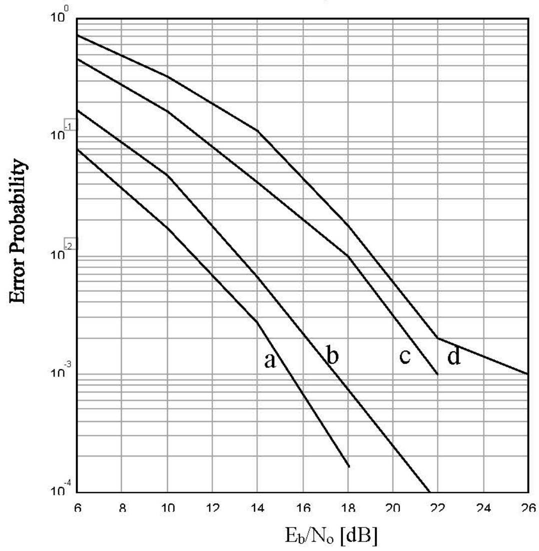



**Figure 38: a) BER for coherent detection, b) BER for differential detection in the frequency domain, c) Packet Error Ratio (PER) for coherent detection, d) PER for differential detection.**

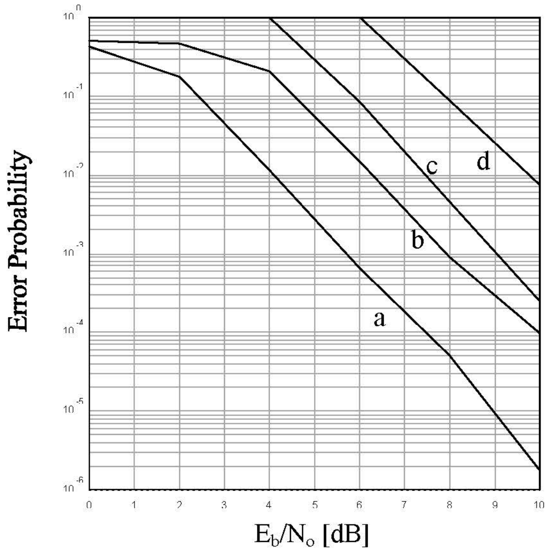



**Figure 39: BER and PER for perfect power control, a) BER for coherent detection, b) BER for differential detection, c) PER for coherent detection, d) PER for differential detection**

The 5 Hz Doppler in the indoor channel model A has no effect at all, because the packets are too small to benefit from time diversity. Even for circuit switched data, the maximum interleaving time is too short to get a significant improvement. So, the BER plots apply to any rate, provided that a proper interleaving in frequency is done such that the system benefits from the full frequency diversity.

# 12. System Simulation Results (Differential Operation)

The simulations were carried out according to the system deployment scenarios, mobility models and user satisfaction criteria of ETR-0402. Evaluation results were conducted by simulation with assumptions based on ETR-0402. The details of the simulation conditions are described before presenting the results. Results for circuit switched traffic and packet traffic are presented. Further results will be presented at a later date.

## 12.1 Simulation Conditions

### 12.1.1 Overview of System Level Simulation

The structure of the system level simulation is shown in Figure 40.

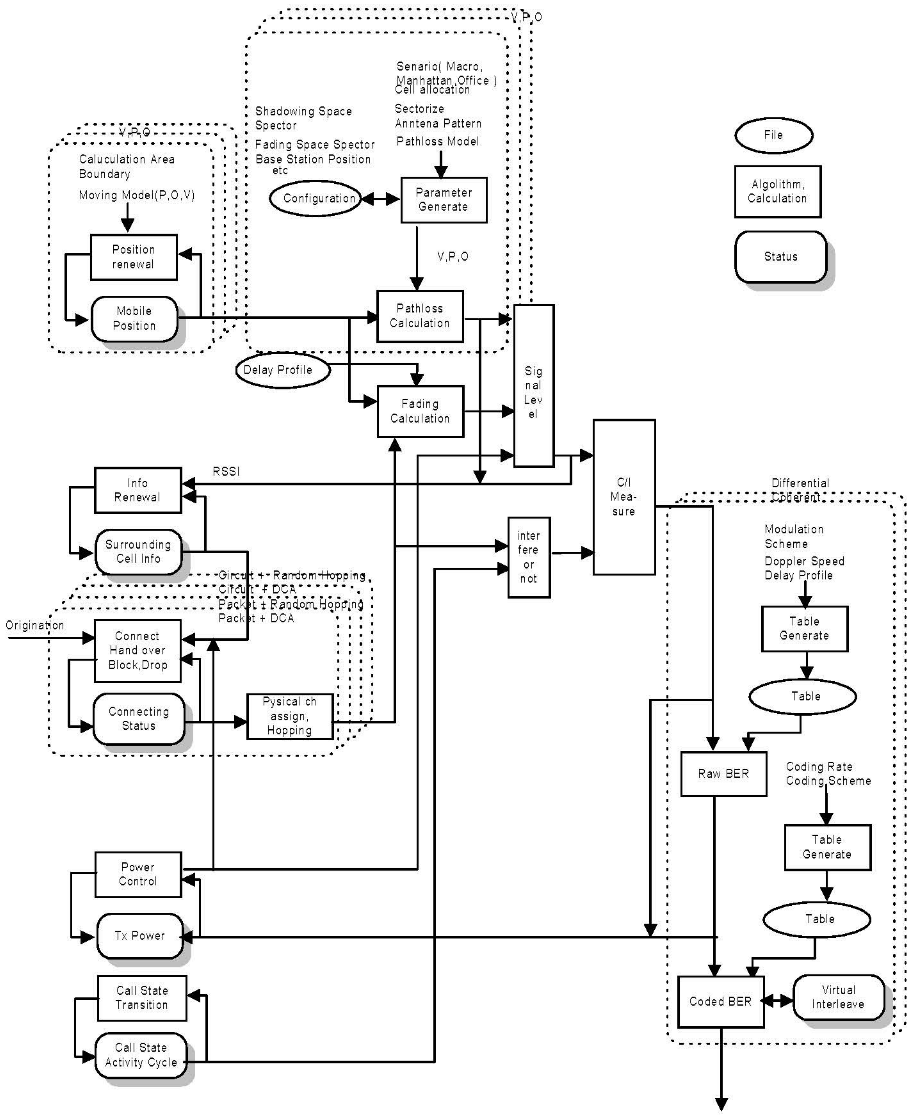



**Figure 40: Structure of System Level Simulation**

In the system level simulation, the coded BER is calculated by using a look up table. The

C/(I+N) for each slot is collected, and the raw BER is found. (The raw BER are calculated values for all slots within one interleaver frame.) The mean raw BER is then calculated, and finally, the coded BER is calculate by mean raw BER using another look up table. These look up tables are created by the link level simulation. The impact of the channel impulse response model is taken into account for each look up table for each specific evaluation environment. For diversity antenna reception, we collect the raw BER value for each branch, and calculate the mean raw BER.

In actual operation, a cross interleaver will be implemented to reduce transmission delays. However for the system level simulations a cross interleaver is not used to simplify simulations. This does not influence the performance. Interleaving is achieved over 18.46msec (speech service). Currently, only co-channel interference from other cells is taken account, and the interference caused by adjacent channel spurious emission is ignored.
For speech services, OFDMA uses a 4 TDMA structure with channel spacing of 100kHz. For a 15MHz system bandwidth the OFDMA system has 600 (15000kHz / 100kHz * 4 TDMA) logical channels. To reduce the simulation time only 1 time slot was simulated. The performance in the other slots was assumed to be the same. In addition, a system bandwidth of only 3.2 MHz was used in order to reduce the number of logical channels and shorten the simulation time. Evaluation with 3.2 MHz bandwidth (32 logical channel per cell) was regarded as reliable enough to measure the precise interference distribution/density.

32 logical channel per cell is however too small to achieve the required trunking efficiency. For a 90% system load which corresponds to 600 logical channel per cell, all of the system traffic can be accommodated without blocking. By evaluating the same load of the system which has only 32 logical channel per cell, the system will block about 8% of the users (see Figure 41). To compensate for this the blocked user rate is calculated by simulating the exact blocked user rate assuming 600 logical channel by using another look up table.

Figure 42 shows the results for satisfied users versus system load for 3.2 MHz and 32 channels and Figure 43 shows percentage of blocked users versus accommodated load for the same conditions. By using the look up table the results for 600 channels in 15 MHz are shown in Figure 44. It can therefore be seen that blocking does not occur at a load of 135kbps/MHz/cell. For a speech service with 15MHz system bandwidth, blocking can therefore be ignored. Additionally, at 32 channels per cell case, it is impossible to achieve a load of greater than 135 kbps/MHz/cell.

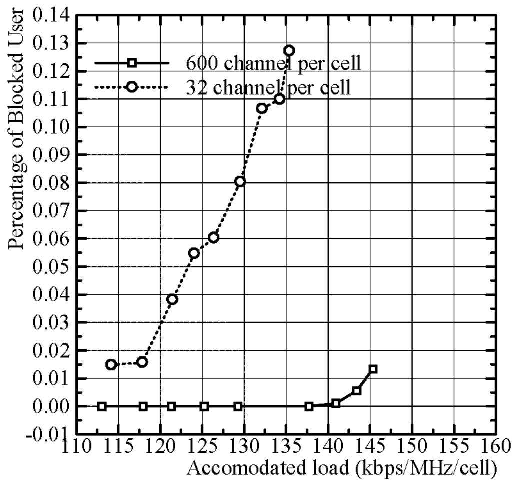



**Figure 41: Blocking versus Load**

It can be seen than at a load of 135kbps/MHz/cell, blocking does not occur. For a speech service with 15MHz system bandwidth blocking can therefore be ignored. Additionally, at 32 channels per cell case, it is impossible to achieve a load of greater than 135 kbps/MHz/cell.

The system level simulation used a simulation time of only 120s to collect the statistical values for the evaluation of speech service scenario. Ideally a longer time is needed and results with a longer time will be provided before December.

For each environment (Pedestrian/Vehicular), quality statistical are only measured on marked BS which are allocated in the middle of the assumed service area. For evaluation of the pedestrian environment 66 base stations are needed to cover the whole of the service area including 6 marked BS. For evaluation of the vehicular environment 21 base stations are needed to cover the service area including 3 marked BS.

## 12.1.2 Statistical calculations

1) System load
   The system load is calculated in the whole service area using the equation in document ETR 0402. The calculated system load does not include blocked user.
1. Number of handoffs per call
   This value is also calculated for the whole of the service area, by counting all handoff execution and number of total calls generated during the observation duration.
2. Blocked users
   Blocked users are only collected at marked BS, although blocking occurs at other base stations. Each new MS attempts to connect to the BS which has the lowest pathloss and long term fading. Blocking occurs when this is a shortage of channels (no more logical channels available at this BS).
3. Dropped users
   Dropped users are only collected at marked BS, though dropping might occur at other base stations, as described in ETR-0402. Connections will drop according to condition described in ETR 0402.
4. Not satisfied users
   Not satisfied users are calculated according to conditions described in ETR-0402.

At every 0.5 seconds, the BER is collected at every connection within the service area. The quality statistical calculation is also performed at every MS which are connected to the marked BS. ( If a MS was originally connected to a 'marked BS' as is disconnected during this period it is not included.)

5. Total BER
   ETR-0402 does not require to submit this quality statistical value, but it has been calculated as reference. This value is collected for the whole of the service area.

### 12.1.3 Pathloss calculation

According to ETR-0402, mobiles position should be updated at every shadowing decorrelation length. As OFDMA operates fast power control, discrete mobility of MS is not acceptable for precise evaluation. Samples of long term fading value are therefore collected at every decorrelation length and interpolation performed for calculating long term fading for every point between the discrete samples of the long term fading.

### 12.1.4 Fading calculation

Fading is created according to the channel impulse response model described in section B.1.4.2 of ETR-0402. The total number of fading spectors is set to 16. The fading envelope is calculated for each diversity antenna branch. The distance between diversity antenna is set as 7.5cm (at MS).

### 12.1.5 Neighbour BS Information

All BS inside the system area have a priori knowledge of neighbour BS. This information is used for cell search and handoff.

### 12.1.6 Interference Restriction

This procedure reduces the simulation time. To be precise the co-channel interference power should be collected from all cells. However, the total interference power is dominated by a couple of relatively large interferes. For instance, a -20dB interference from 1 MS is much larger than the sum of -40dB interference from 10 or more MS. In the simulation therefore, the interference power is calculated by restricting the source of interference as follows.

L1[dB] is defined as the pathloss between MS being considered and its connected BS. This base station is named Bsa.

L2[dB] is defined as the pathloss between MS and other cell's BS. These basestations are named BSx.

1) If L1 + Threshold < L2,
   To BSx, up link interference from this MS should be omitted.
   To this MS, down link interference from BSx should be omitted.
   Threshold is set to 35[dB].

Each MS will therefore search all interference candidates from the BS and check to see it is visible from the MS location. If candidate is not treated as visible, then this MS will ignore it when calculating interference.

This procedure is done at every update of the MS position.

For uplink the same procedure is used.

### 12.1.7 Traffic Management

Circuit switched traffic is expressed by the Poisson process with additional minimum call duration, according to ETR-0402. Each call is generated after calculated interval from previous call generation. Calls will be terminated when call termination timer is expired, or when call is forced to be dropped. Dropped calls occur according to condition described in ETR-0402. At system level simulation, 1 MS is used for initialisation and the number of communicating MS increases rapidly during the first 10 seconds. The total traffic then reaches input load with some variation according to Poisson process.

If activity factor is 100%, then ON state will last until call termination. If activity factor is not 100%, then another call state will be selected at each state of timer expiration. ON state and OFF state timer are set according to description in ETR-0402. During the OFF duration, ACCH is transmitted with a lower bit rate (1/4 or 1/8 compared to continuous TCH transmission) to maintain power control. In the current system level simulation no information is transmitted during the 'OFF' state to simplify simulations.

### 12.1.8 MS Mobility

MS mobility is implemented according to ETR-0402 except the frequency of the location updates As described above, the MS location is updated more frequently than the long term fading decorrelation length. The MS location is updated at every 1.15msec which is 1 TDMA frame duration. If the MS moves outside the service area for the vehicular case, the MS is forced to go back in the opposite direction to stay in the service area. In the case of pedestrian, every MS is located in the centre of the street.

### 12.1.9 Handoff

Handoff is triggered by a simple pathloss comparison which does not including fading attenuation. The MS attempts to connect to the closest BS during handover. Handoff check is initiated every 73.6 msec. If the BS which the MS attempts to create a connection, does not have vacant channel, handoff will fail, and this MS will stay connected to the previous BS.

### 12.1.10 Power Control

Power control is achieved for every slot by returned power control command. Power control command is returned to transmitter without errors, as ETR-0402 requires to evaluate up/down link separately. Power control step is set to 1dB. Power control command is reflected to exact transmission with some time lag. In case of 4 TDMA structure, returned power control command is reflected 3 TDMA frames later.

In the case of the multi slot usage for higher bit rate transmission, the power control command will be achieved uniquely for 1 time slot unit. Power control command is decided by mean quality among received 1 time slot unit.

## 12.2 System Level Simulation Results (Speech)

Speech service system capacity (circuit switched service) has been evaluated using dynamic system simulations. A voice activity of 50% is considered.

### 12.2.1 Outdoor to Indoor and Pedestrian A

The following figures show the speech service spectrum efficiency for an outdoor to Indoor and pedestrian A environment. Figure 42 shows the satisfied user rate versus system load using the described system level simulation.

As explained before, this evaluation is based on system band width of 3.2MHz, considering 15MHz bandwidth we can eliminate all blocked users from the 'unsatisfied users'. Using the full bandwidth of 15MHz the accommodated load is smaller than 135kbps/MHz/cell, so the actual rate of blocked users is 0% (considering Figure 43 which shows blocked user rate versus system load at 3.2Mhz).

Finally Figure 44 shows the final system level simulation results assuming 15MHz system bandwidth (satisfied user rate versus system load). No dropping was observed at all evaluated system loads, the mean number of handoff procedures per user is 2.7.

It should be noted that OFDMA has the ability to accommodate more than the presented load figures because all plots in Figure 44 show a satisfied user rate above 98%. As described before, we could not measure quality statistics at higher load (occurrence of blocking).

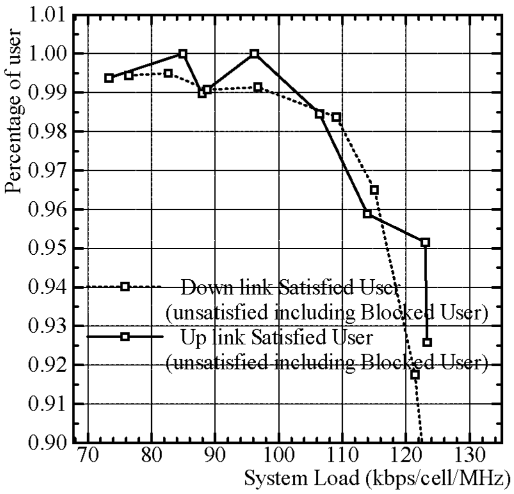



**Figure 42: System Bandwidth 3.2MHz**

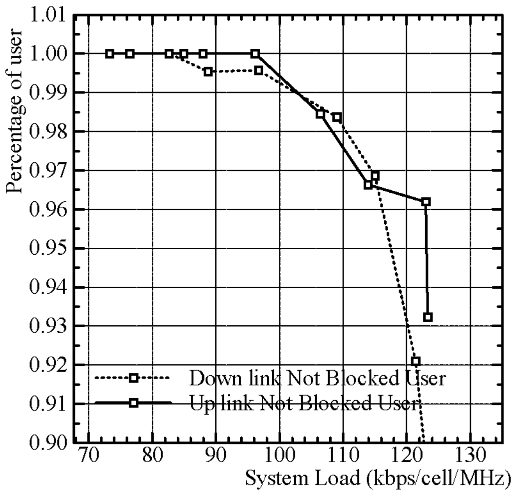



**Figure 43: System Bandwidth 3.2MHz**

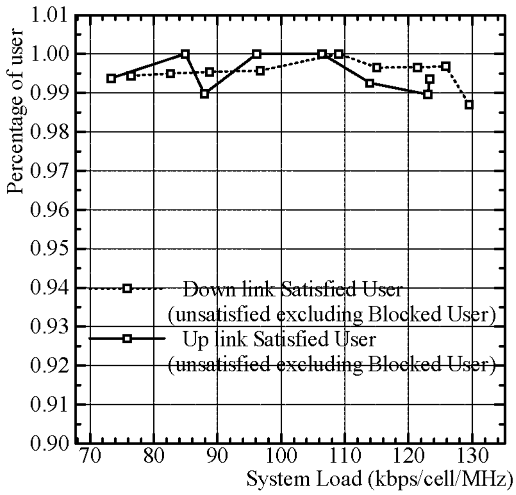



**Figure 44: System Bandwidth 15MHz**

## 12.2.2 Vehicular A

The following figures show the spectrum efficiency for a speech service scenario at Vehicular A environment. Figure 46 shows the satisfied user rate versus system load evaluated by dynamic system level simulation. Figure 45 shows the blocked user rate versus system load and Figure 47 finally gives the system level simulation results assuming 15MHz system bandwidth (here again the assumption of no blocking with a system bandwidth of 15MHz is valid). No dropped users were observed at all evaluated system loads, the mean number of handoff procedures per user is 3.3.

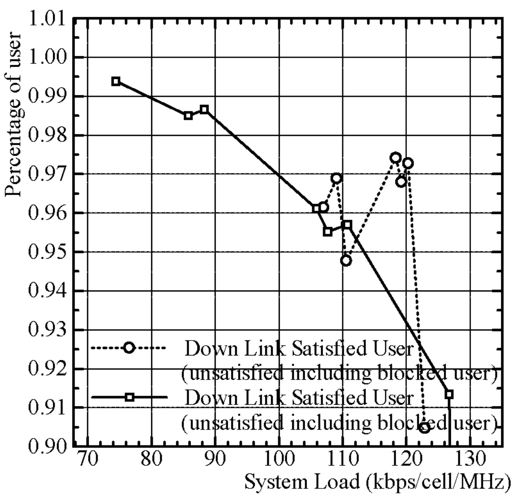



**Figure 46: System Bandwidth 3.2MHz**

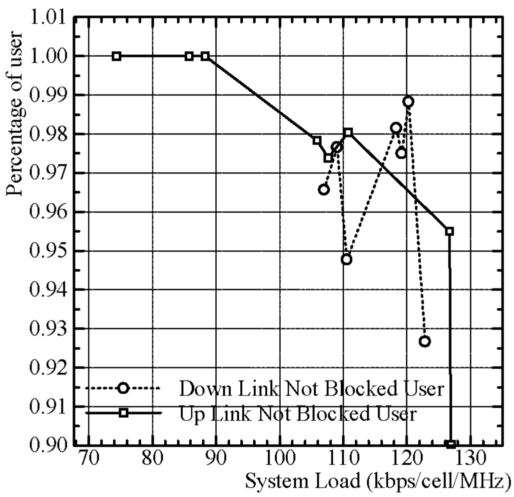



**Figure 45: System Bandwidth 3.2MHz**

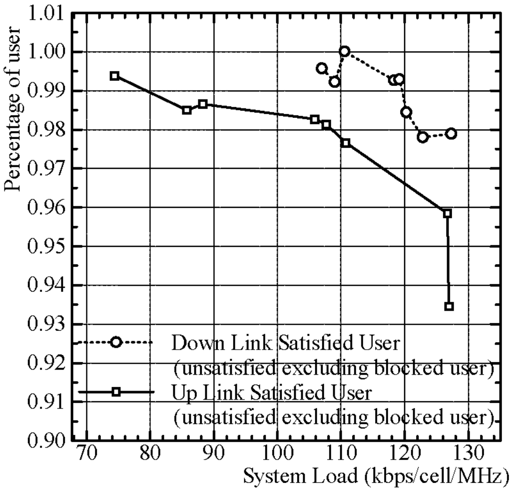
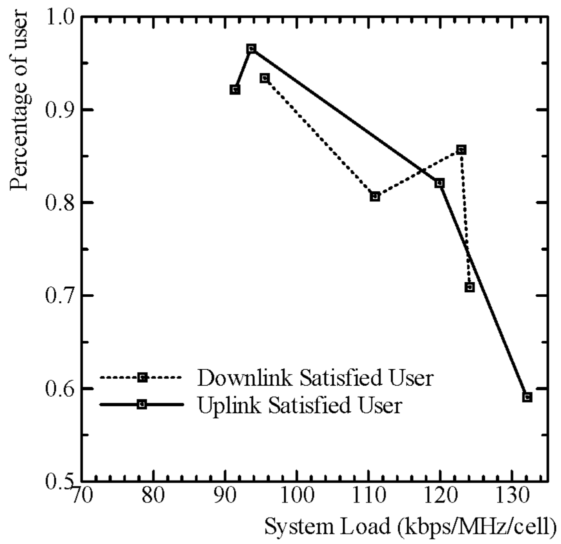



**Figure 47: System Bandwidth 15MHz**

### 12.2.3 Indoor Office A

The following figures show the spectrum efficiency for a speech service scenario for the indoor office A environment. Figure 48 shows the satisfied user rate versus system load evaluated by the dynamic system level simulation. Figure 44 shows the blocked user rate versus system load and Figure 50 gives the system level bandwidth of 15MHz is valid). No dropped users were observed at all evaluated system loads. The simulation results assuming 15MHz system bandwidth (here again the assumption of no blocking with a system summarised results are shown in Table 12.



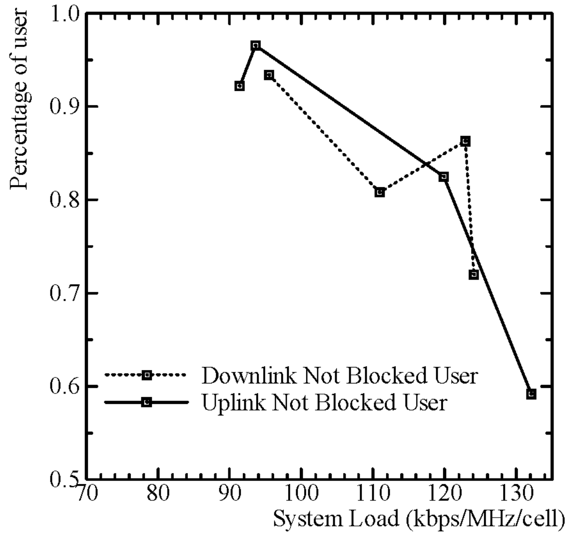




**Figure 48 System Bandwidth 3.2 MHz** **Figure 49 System Bandwidth 3.2 MHz**

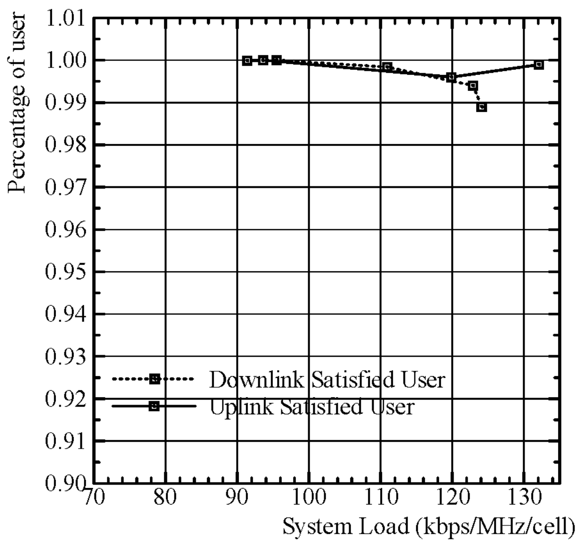



**Figure 50 System Bandwidth 15 MHz**

### 12.2.4 Speech System Level Simulation (Summary)

Table 12 summarises the system level simulation results for speech services according to ETR0402.

**Table 12: Speech System Level Simulation Summary**

| Service | Environment | Cell Capacity (#User/MHz/Cell) (UL/DL) | Spectrum Efficiency (kbps/MHz/Cell) (UL/DL) | Mean BER (UL/DL) |
|---|---|---|---|---|
| Speech (8kbps, 50% VA) | Indoor Office A | 33.0 / 31.0 | 132 / 124 | 6.5e-5 / 4.0e-5 |
| | Outdoor to Indoor and Pedestrian A | 30.75 / 32.25 | 123 / 129 | 5.8e-5 / 2.2e-5 |
| | Vehicular A | 27.0 / 30.5 | 108 / 122 | 2.1e-4 / 3.7e-4 |

For speech services the BDMA system requires only a very small guard band (e.g. 200kHz or 400kHz on each side) to full fill adjacent system spurious emission requirements. Therefore the results we presented should be normalised by a factor of (15-2*0.4)/15=0.95.

## 12.3 System Level Simulation Results (LCD 384)

### 12.3.1 Vehicular A

The following figures show results of the spectrum efficiency simulation of LCD 384kbps services for the Vehicular A environment. For LCD 384kbps service system level simulation, we assume 13.6MHz system bandwidth and the rest of 1.4 MHz as guard band. LCD 384kbps service requires 800kHz bandwidth (8 bandslots) per connection, in total 17 carriers are available to operate LCD 384 services using 13.6MHz.
Two scenarios were simulated, the first simulation uses the maximum transmit power specified in the link budget template(see Table 1.3 in ETR-0402), and the second simulation uses optimised transmitter power[2] for the OFDMA SRTT.

**Table 13: LCD 384 Concept Optimising Parameters**

| | | Downlink | Uplink |
|---|---|---|---|
| Test Environment | | Vehicular A | Vehicular A |
| Test Service | | LCD 384 | LCD 384 |
| **Concept Optimising Parameters** | | | |
| Max. TX power per Traffic Channel | [dBm] | 45.0 | 33.0 |
| Average TX power per Traffic Channel | [dBm] | 44.4 | 32.4 |
| TX antenna gain | [dBi] | 17 | 2 |

[2] For the down-link the maximum TX power per band-time slot is the same TX power specified in ETR-0402 to support voice services (36.0dBm), therefore no modification in the BS transmitter is necessary to operate a LCD 384kBps service.
For the up-link the maximum TX power of the MS is the same as defined in the GSM specifications (2 W) which is a realistic assumption.

| | | | |
|---|---|---|---|
| RX antenna gain | [dBi] | 2 | 17 |

Figure 51 shows the satisfied user rate versus system load and Figure 52 shows the dropped user rate versus system load. No blocking was observed at the simulated system load values. These results are achieved using the specified (ETR0402) maximum transmitter power. We emphasise that because of the fundamental transmitter power shortage, there is no possibility to accommodate a certain amount of users under the (non optimised) conditions described in ETR-0402. We believe this problem is not limited to the OFDMA SRTT. No information can be received if the received Eb/No is smaller than the required Eb/No, this is valid for any radio access scheme.

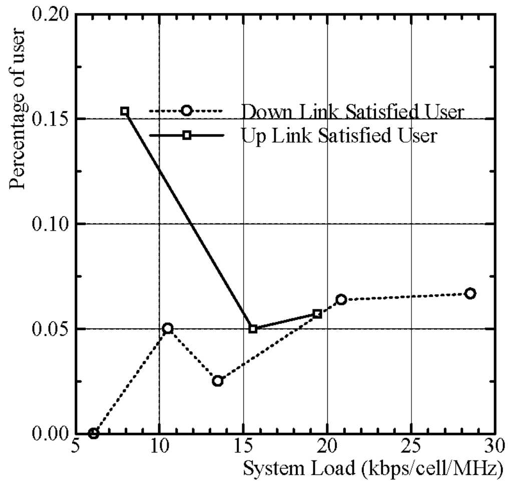



**Figure 51: Satisfied User Rate**

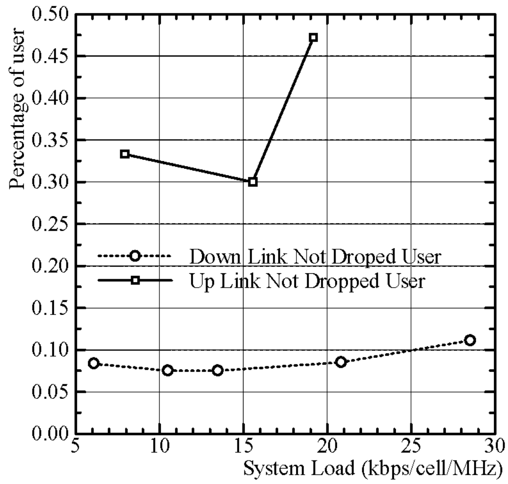



**Figure 52: Not Dropped User Rate**

Figure 53 shows the satisfied user rate versus system load, and Figure 54 shows blocked user rate versus system load. No dropping was observed at each simulated system load, These results are based on the optimised transmitter power assumption.

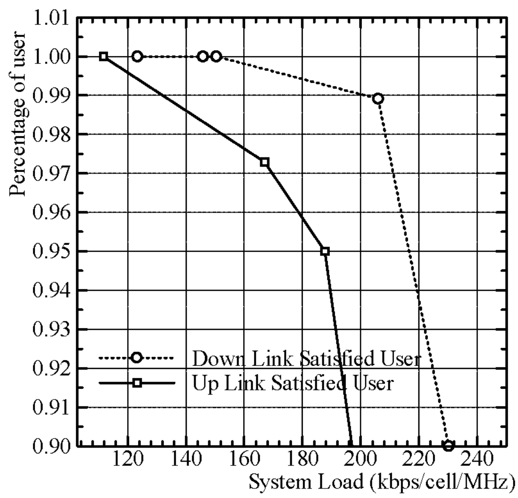



**Figure 53: Satisfied User Rate**

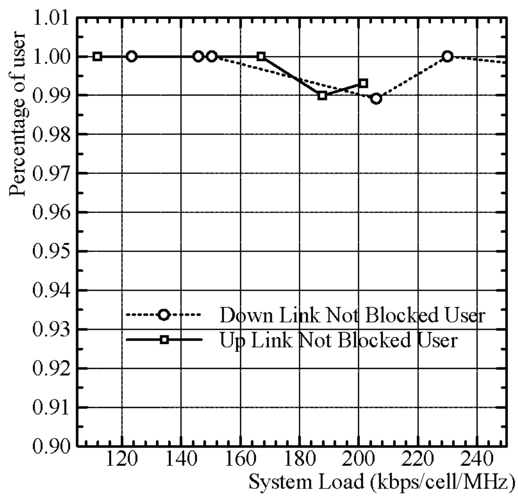



**Figure 54: Not blocked User Rate**

The following table summarises the results for LCD 384 services.

**Table 14: LCD 384 System Level Simulation Summary**

| Service | Environment | Cell Capacity (#User/MHz/Cell) (UL/DL) | Spectrum Efficiency (kbps/MHz/Cell) (UL/DL) | Mean BER (UL/DL) |
|---|---|---|---|---|
| LCD 384kbps (with specified transmitter power) | Indoor Office A | T.B.D. / T.B.D. | T.B.D. / T.B.D. | T.B.D. / T.B.D. |
| | Outdoor to Indoor and Pedestrian A | T.B.D. / T.B.D. | T.B.D. / T.B.D. | T.B.D. / T.B.D. |
| | Vehicular A | / | None / None | not measured |
| LCD 384kbps (with optimised transmitter power) | Indoor Office A | T.B.D. / T.B.D. | T.B.D. / T.B.D. | T.B.D. / T.B.D. |
| | Outdoor to Indoor and Pedestrian A | T.B.D. / T.B.D. | T.B.D. / T.B.D. | T.B.D. / T.B.D. |
| | Vehicular A | / | 152 / 208 | not measured |

For 800kHz services like LCD 384kbps, the BDMA system requires approximately 700-800kHz guard band to fulfil adjacent system spurious emission requirements. Therefore the results we presented should be normalised by a factor of (15-2*0.7)/15=0.91

## 12.4 System Level Simulation Results (UDD384)

System level simulations were conducted for the UDD384 packet services. The simulations were conducted in accordance with 0402 and SMG2 G18/97. A satisfied user is therefore defined as one in which a throughput of 10 % of the target bit rate can be maintained. Calls with packet services are never dropped. In a similar way to the circuit switched services a look up table is used to derive the block (or packet) error rate from the raw BER.

### 12.4.1 Outdoor to Indoor and Pedestrian A

System results for the UDD 384 services (Mode B) are shown in Figure 55 for the uplink and downlink. These results are for a system bandwidth of 3.2 MHz. The results are therefore likely to increase for the case of 15 MHz due to the availability of more channels and consequent decrease in blocking. The results are summarised in Table 15.

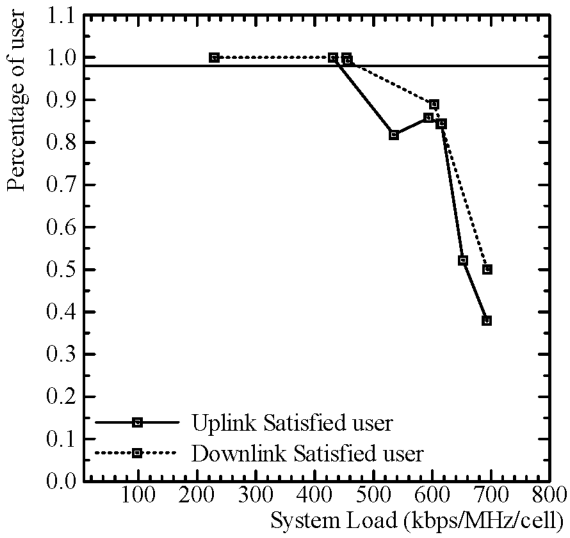



**Figure 55 System Bandwidth 3.2 MHz**

**Table 15 UDD 384 Pedestrian Simulation Summary**

| | Environment | Cell Capacity (#User/MHz/Cell) (UL/DL) | Spectrum Efficiency (kbps/MHz/Cell) (UL/DL) |
|---|---|---|---|
| UDD384 (10%) | Outdoor to Indoor and Pedestrian A | | 440 / 465 |

## 12.5 System Level Simulation Results (UDD2048)

### 12.5.1 Indoor Office A

Preliminary results for the UDD 2048 services (Mode B) are shown in Figure 56 for the uplink and downlink. It is important to note that these are preliminary results and that the system parameters have not yet been optimised to yield the best performance. These results are for a system bandwidth of 15 MHz and a system with only one floor. The results are summarised in Table 16.

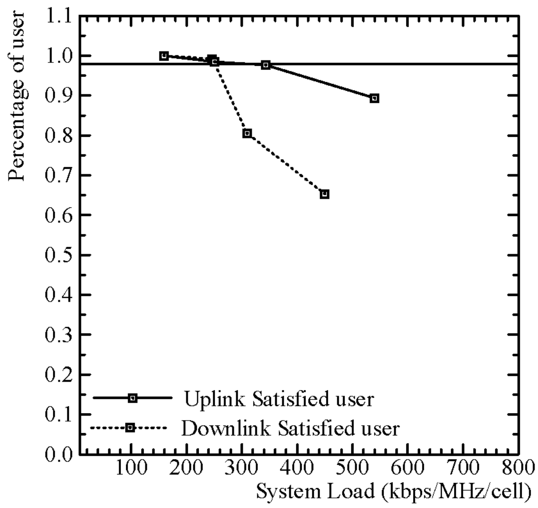



**Figure 56 System Bandwidth 15 MHz**

**Table 16 UDD 2048 Indoor Simulation Summary**

| | Environment | Cell Capacity (#User/MHz/Cell) (UL/DL) | Spectrum Efficiency (kbps/MHz/Cell) (UL/DL) |
|---|---|---|---|
| UDD2048 (10%) | Indoor | | 240 / 240 |

## 12.6 System Level Simulation Results (50%speech+50%UDD384)

### 12.6.1 Indoor Office A

These simulations are in progress and results will be submitted shortly.

# 13. Conclusion

In this evaluation report we have provided a description of the basic functional blocks that make up the OFDMA system. From this description it should be clear that the OFDMA proposal can be considered as a hybrid OFDM-TDMA scheme.

- The benefits of using OFDM as the underlying modulation scheme, is that it greatly reduces the required hardware complexity and provides a degree of flexibility in the frequency domain that enables two MACs to be supported by the same basic PHY layer. This inherent frequency flexibility provides operators with frequency deployment options that allows the support of asymmetric up and down links as well as smaller re-farmed portions of spectrum.
- The benefits of the two software driven TDMA style MACs allow the OFDMA proposal to realistically provide the full complement of UMTS services (including unlicensed operation & high bit-rate support) in a spectrally efficient manner with relatively low complexity terminals.
- Both MACs have been deliberately designed to share the same basic TDMA framing structure of GSM, making the possibility of dual mode UMTS/GSM terminals/core networks that much more realistic.
- In addition to this ability to co-exist and work with existing 2nd generation networks, we believe that OFDMA also has the flexibility to expand its horizons for later developments of UMTS.
- Enhancement techniques already available and proven for TDMA system can be applied to OFDMA easily (e.g. HCS, directional antennas).

In the near future we intend to release further results showing the system capacity for packet data transfer services. We also have work under way to develop a hardware testbed. In the meantime, we look forward to your comments and questions.

# 14. Annex

# 15. Annex

## 15.1 System Level Simulation Updates

During the preparation of the evaluation report new results with longer simulation time were carried out for the system level simulation. This annex contains the latest results achieved.

### 15.1.1 Vehicular A - LCD 384

This section contains new simulation results for the LCD 384 service in the Vehicular A environment, the corresponding chapter is 12.3.1.

Figure 57 shows the downlink system performance for the LCD 384 service in Vehicular A environment with different simulation times. It can be seen that the results produced by the 1200 second simulation produce higher system load figure than those with the 120 second simulation.

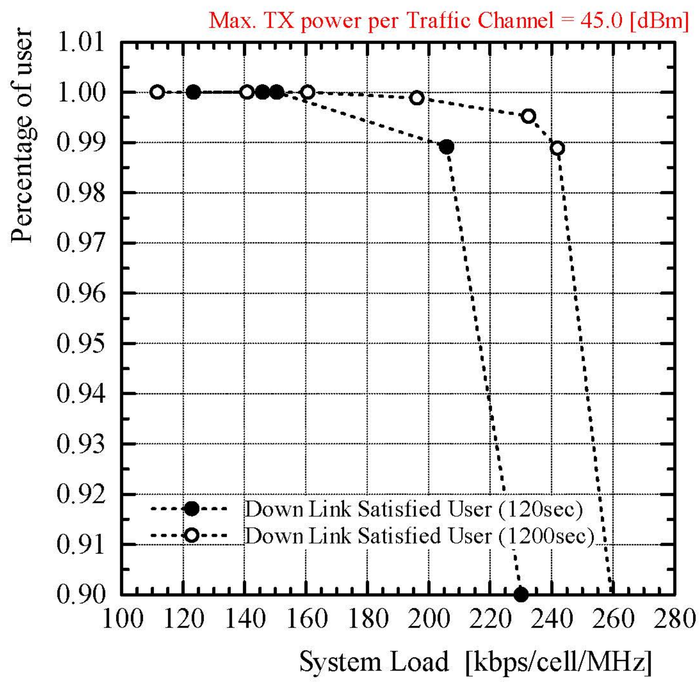



**Figure 57 Downlink simulation system performance with different simulation time**

### 15.1.2 Speech

This section contains new simulation results for the speech service in the Vehicular A environment, the corresponding chapter is 12.2.2.
Figure 58 shows the system performance of the speech service with 15 MHz bandwidth, Vehicular A environment and 480 seconds observation time. The call duration has also been reduced to 40 seconds.

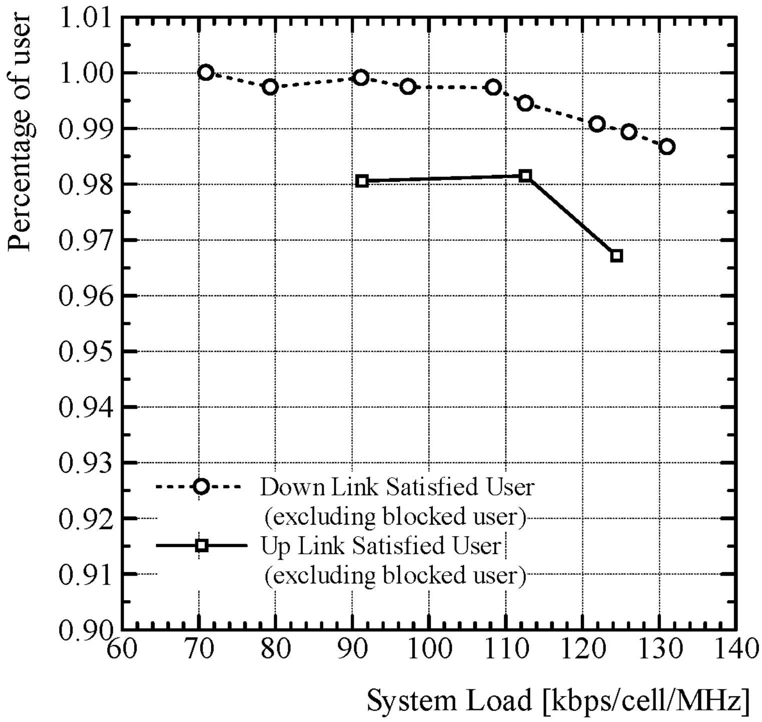



**Figure 58 System load performance (Speech) with longer observation time (480 s)**

As can be seen from these results the longer simulation time causes a smoother load curved to be produced due to the improved statistics of the simulation results. What is more important, however, is that system load for 98 % satisfied user is higher (increase of 10%) for the longer simulation time. This indicates that the results shown in the Evaluation report are pessimistic.

### 15.1.3 UDD 384 - Pedestrian A

This section contains new simulation results for the UDD384 service in the Pedestrian/Indoor to Outdoor environment, the corresponding chapter is 12.4.1.

These are initial result for the downlink for mode A of UDD services.
The simulation has not terminated to the 98% user satisfaction, but the performance of mode A are better than for mode B.
The PDF graphs shown in Figure 61, Figure 62, Figure 63 are shown for three different loads 420, 290 and 155 kbit/s respectively. The two vertical lines indicate the PDF at 10 % of the of the target bit rate (38.4 kbit/s ) and 100 % of the target bit rate (384 kbit/s).

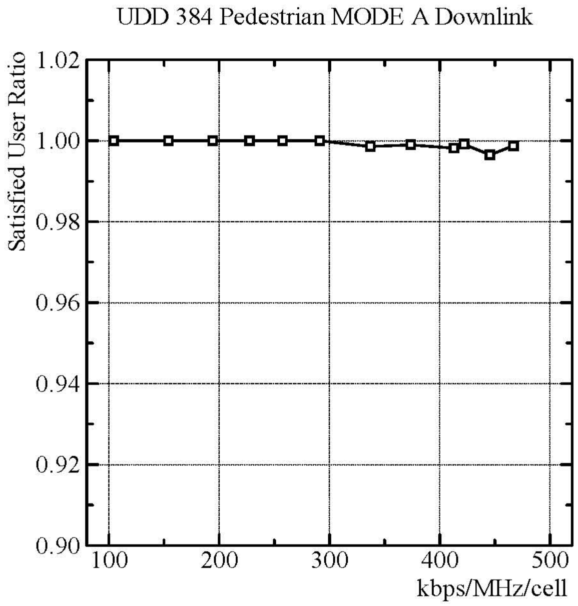



**Figure 59 UDD 384 Mode A - Percentage of satisfied users (DL)**

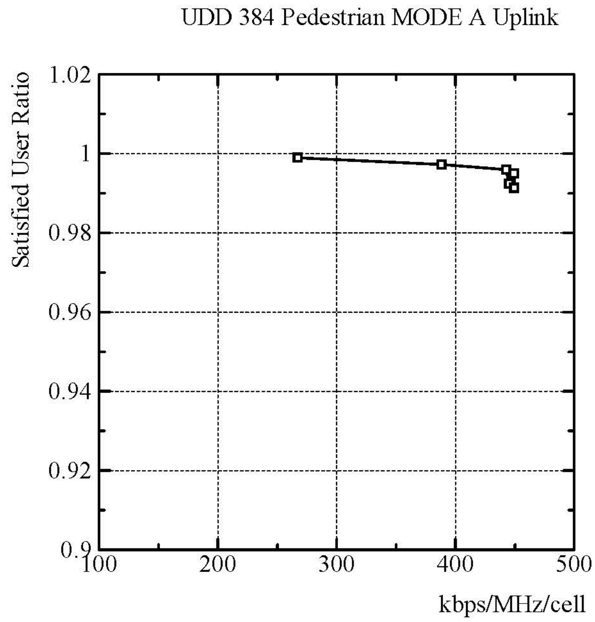
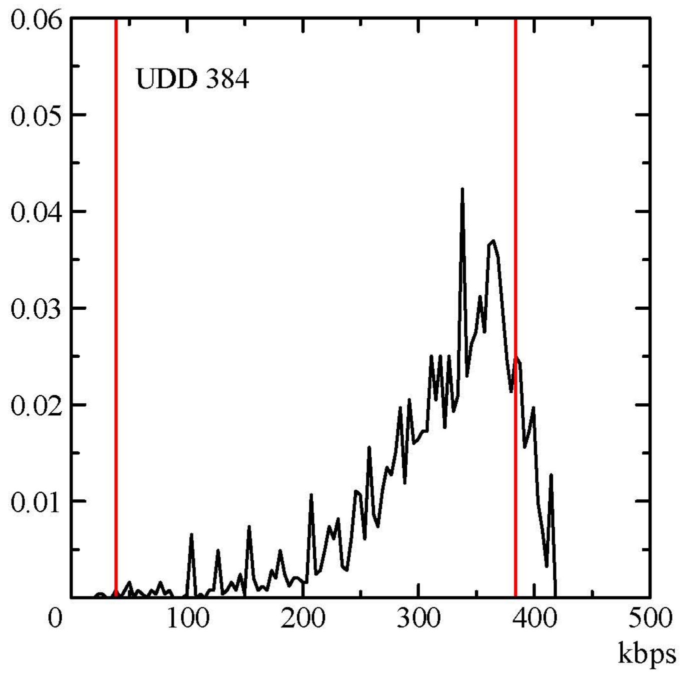



**Figure 60: UDD 384 Mode A - Percentage of satisfied users (UL)**




420kbps/MHz/cell

**Figure 61 - PDF of mean bit rate at system load of 420 kbit/s/MHz/cell**

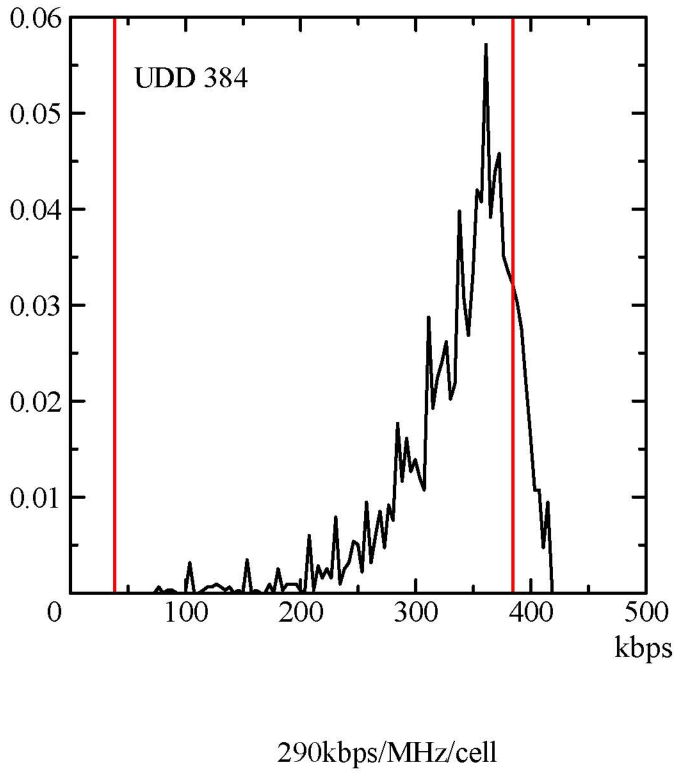



**Figure 62 PDF of mean bit rate for system load of 290 kbit/s/MHz/Cell**

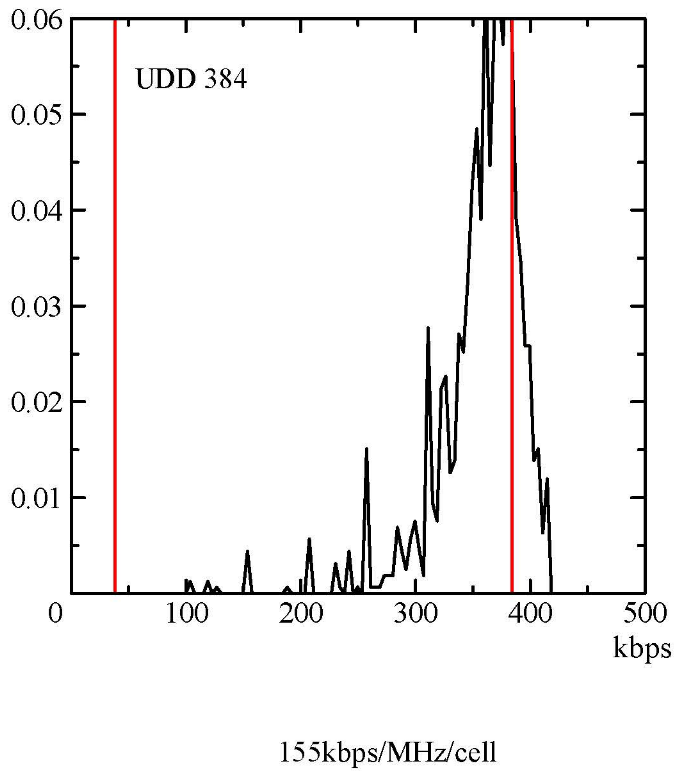



**Figure 63 PDF of mean bit rate for system load of 155 kbit/s/MHz/Cell**

## 15.2 Abbreviations

| | |
|---|---|
| ***BCCH*** | Broadcast control channel |
| ***CDMA*** | Code Division Multiple Access |
| ***DCA*** | Dynamic channel assignment |
| ***DCCH*** | Dedicated control channel |
| ***DL*** | Downlink |
| ***IACH*** | Initial acquisition channel |
| ***KERO*** | Knowledge enclosed reference operation |
| ***MRC*** | Maximal ratio combining |
| ***OBO*** | Output Back Off |
| ***OFDMA*** | Orthogonal Frequency Multiple Access |
| ***QPSK*** | Quadrature Phase Shift Keying |
| ***RACH*** | Random access channel |
| ***ROT*** | Random orthogonal transform |
| ***RPS*** | Random phase shift |
| ***SFH*** | Slow Frequency Hopping |
| ***TDMA*** | Time Division Multiple Access |
| ***UL*** | Uplink |
| ***UMTS*** | Universal Mobile Telephone System |

## 15.3 References

***[SMG50402]*** ETR/SMG-50402 Version 0.9.5.
ETSI draft specification of the Selection procedure for the choice of radio transmission technologies of the Universal Mobile Telecommunication System (UMTS).

***[Mueller97]*** Mueller S., Baeuml R., Fischer R., Huber B; 'OFMD with reduced Peak-to-Average Power Ratio by Multiple Signal Representation; Annals of Telecommunications; Vol. 52; No. 1-2; pp. 58-67, February 1997.

***[Olofsson95]*** Olofsson H., Naslund J., Sköld J.; 'Interference Diversity Gain in Frequency Hopping GSM'; Proceedings IEEE Vehicular Technology Conference (VTC); Chicago; pp. 102-106; June 1995

***[Pauli97]*** Pauli M., Kuchenbecker H.P.; 'Minimisation of the intermodulation distortion of a nonlinearilty amplified OFDM signal'; Wireless Personal Communications; Vol. 4; No. 1; pp. 93-101; January 1997,.

# OFDMA Evaluation Report

## The Multiple Access Scheme Proposal for the UMTS Terrestrial Radio Air Interface (UTRA)

## Part 2

## Link Budget and Technology Description Template

### *Introduction:*

This document contains the link budgets for speech, LCD 144 and LCD384.
For Speech also the new test cases of Vehicular B channel model and MS speed of 250km/h has been tested with excellent performance.

The second part of this document contains the technology description template for the OFDMA system (according to ETR30.03).

### *Table of Content*

# 1. Link Budget Templates

## *1.1 Link Budget Speech*

| Test environment | | (O) | | (P) | | (V) Vehicular A 120[km/h] | |
|---|---|---|---|---|---|---|---|
| Item | | Down Link | Up Link | Down Link | Up Link | Down Link | Up Link |
| Test service | | SP | SP | SP | SP | SP | SP |
| Ave. Tx Power per traffic Ch | [dBm] | 10.0 | 4.0 | 20.0 | 14.0 | 30.0 | 24.0 |
| (a1) Max Tx Power per traffic Ch | [dBm] | 16.0 | 10.0 | 26.0 | 20.0 | 36.0 | 30.0 |
| (a2) Max Total Tx Power | [dBm] | 16.0 | 10.0 | 26.0 | 20.0 | 36.0 | 30.0 |
| (b) Cable, connector, and combiner losses | [dB] | 2 | 0 | 2 | 0 | 2 | 0 |
| (c) Transmitter Antenna gain | [dBi] | 2 | 0 | 10 | 0 | 13 | 0 |
| (d1) Tx e.i.r.p. per traffic ch=(a1-b+c) | [dBm] | 16.0 | 10.0 | 34.0 | 20.0 | 47.0 | 30.0 |
| (d2) Total Tx e.i.r.p. = (a2-b+c) | [dBm] | 16.0 | 10.0 | 34.0 | 20.0 | 47.0 | 30.0 |
| (e) Receiver Antenna Gain | [dBi] | 0 | 2 | 0 | 10 | 0 | 13 |
| (f) Cable and Connector Losses | [dB] | 0 | 2 | 0 | 2 | 0 | 2 |
| (g) Receiver Noise Figure | [dB] | 5 | 5 | 5 | 5 | 5 | 5 |
| (h) Thermal Noise Density | [dBm/Hz] | -174 | -174 | -174 | -174 | -174 | -174 |
| (i) Receiver Interference Density | [dBm/Hz] | -Infty | -Infty | -Infty | -Infty | -Infty | -Infty |
| (j) total effective noise plus interfererence | [dBm/Hz] | -169 | -169 | -169 | -169 | -169 | -169 |
| (k)Information Rate (10 log (Rb)) | [dBHz] | 45.05 | 45.05 | 45.05 | 45.05 | 45.05 | 45.05 |
| | | 8.0[kbps] x 4 | | | | | |
| (l) Required Eb/(No+Io) with no power control | [dB] | 10.0 | 10.0 | 11.2 | 11.2 | 5.6 | 5.6 |
| | | including diversity gain | | | | | |
| (m) Receiver sensitivity = (j + k + l) | [dB] | -113.95 | -113.95 | -111.75 | -111.75 | -118.35 | -118.35 |
| (n) Hand-off gain | [dB] | 5.9 | 5.9 | 4.7 | 4.7 | 4.7 | 4.7 |
| (o) Explicit diversity gain | [dB] | 0 | 0 | 0 | 0 | 0 | 0 |
| | | included in req.Eb/No | | | | | |
| (o') Other gain | [dB] | 0 | 0 | 0 | 0 | 0 | 0 |
| (p) Log-normal fade margin | [dB] | 15.4 | 15.4 | 11.3 | 11.3 | 11.3 | 11.3 |
| (q) Maximum path loss = {d1-m+(e-f)+o+n+o' -p} | [dB] | 120.35 | 114.45 | 140.15 | 134.15 | 158.75 | 152.75 |
| (r) Maximum Range | [m] | 600.25 | 381.65 | 635.33 | 449.77 | 6514 | 4511 |

(O) L(R[m]) = 37 + 30log( R[m] ) [dB]
(P) L(R[km]) = 148.03 + 40log( R[km] ) [dB]
(V) L(R[km]) = 128.15 + 37.6log( R[km] ) [dB]

| Test environment | | (O) | | (P) | | (V) Vehicular B 250[km/h] | |
|---|---|---|---|---|---|---|---|
| Item | | Down Link | Up Link | Down Link | Up Link | Down Link | Up Link |
| Test service | | SP | SP | SP | SP | SP | SP |
| Ave. Tx Power per traffic Ch | [dBm] | 10.0 | 4.0 | 20.0 | 14.0 | 30.0 | 24.0 |
| (a1) Max Tx Power per traffic Ch | [dBm] | 16.0 | 10.0 | 26.0 | 20.0 | 36.0 | 30.0 |
| (a2) Max Total Tx Power | [dBm] | 16.0 | 10.0 | 26.0 | 20.0 | 36.0 | 30.0 |
| (b) Cable, connector, and combiner losses | [dB] | 2 | 0 | 2 | 0 | 2 | 0 |
| (c) Transmitter Antenna gain | [dBi] | 2 | 0 | 10 | 0 | 13 | 0 |
| (d1) Tx e.i.r.p. per traffic ch=(a1-b+c) | [dBm] | 16.0 | 10.0 | 34.0 | 20.0 | 47.0 | 30.0 |
| (d2) Total Tx e.i.r.p. = (a2-b+c) | [dBm] | 16.0 | 10.0 | 34.0 | 20.0 | 47.0 | 30.0 |
| (e) Receiver Antenna Gain | [dBi] | 0 | 2 | 0 | 10 | 0 | 13 |
| (f) Cable and Connector Losses | [dB] | 0 | 2 | 0 | 2 | 0 | 2 |
| (g) Receiver Noise Figure | [dB] | 5 | 5 | 5 | 5 | 5 | 5 |
| (h) Thermal Noise Density | [dBm/Hz] | -174 | -174 | -174 | -174 | -174 | -174 |
| (i) Receiver Interference Density | [dBm/Hz] | -Infty | -Infty | -Infty | -Infty | -Infty | -Infty |
| (j) total effective noise plus interfererence | [dBm/Hz] | -169 | -169 | -169 | -169 | -169 | -169 |
| (k)Information Rate (10 log (Rb)) | [dBHz] | 45.05 | 45.05 | 45.05 | 45.05 | 45.05 | 45.05 |
| | | 8.0[kbps] x 4 | | | | | |
| (l) Required Eb/(No+Io) with no power control | [dB] | | | | | 5.7 | 5.7 |
| | | including diversity gain | | | | | |
| (m) Receiver sensitivity = (j + k + l) | [dB] | | | | | - 118.45 | - 118.45 |
| (n) Hand-off gain | [dB] | 5.9 | 5.9 | 4.7 | 4.7 | 4.7 | 4.7 |
| (o) Explicit diversity gain | [dB] | 0 | 0 | 0 | 0 | 0 | 0 |
| | | included in req.Eb/No | | | | | |
| (o') Other gain | [dB] | 0 | 0 | 0 | 0 | 0 | 0 |
| (p) Log-normal fade margin | [dB] | 15.4 | 15.4 | 11.3 | 11.3 | 11.3 | 11.3 |
| (q) Maximum path loss = {d1-m+(e-f)+o+n+o' -p} | [dB] | | | | | 158.85 | 152.85 |
| (r) Maximum Range | [m] | | | | | 6553 | 4538 |

(O) L(R[m]) = 37 + 30log( R[m] ) [dB]
(P) L(R[km]) = 148.03 + 40log( R[km] ) [dB]
(V) L(R[km]) = 128.15 + 37.6log( R[km] ) [dB]

## 1.2 Link Budget LCD144

| Test environment | | (O) | | (P) | | (V) | |
|---|---|---|---|---|---|---|---|
| Item | | Down Link | Up Link | Down Link | Up Link | Down Link | Up Link |
| Test service | | LC144 | LC144 | LC144 | LC144 | LC144 | LC144 |
| Ave. Tx Power per traffic Ch | [dBm] | 10.0 | 4.0 | 20.0 | 14.0 | 30.0 | 24.0 |
| (a1) Max Tx Power per traffic Ch | [dBm] | 10.6 | 4.6 | 20.6 | 14.6 | 30.6 | 24.6 |
| (a2) Max Total Tx Power | [dBm] | 10.6 | 4.6 | 20.6 | 14.6 | 30.6 | 24.6 |
| (b) Cable, connector, and combiner losses | [dB] | 2 | 0 | 2 | 0 | 2 | 0 |
| (c) Transmitter Antenna gain | [dBi] | 2 | 0 | 10 | 0 | 13 | 0 |
| (d1) Tx e.i.r.p. per traffic ch=(a1-b+c) | [dBm] | 10.6 | 4.6 | 28.6 | 14.6 | 41.6 | 24.6 |
| (d2) Total Tx e.i.r.p. = (a2-b+c) | [dBm] | 10.6 | 4.6 | 28.6 | 14.6 | 41.6 | 24.6 |
| (e) Receiver Antenna Gain | [dBi] | 0 | 2 | 0 | 10 | 0 | 13 |
| (f) Cable and Connector Losses | [dB] | 0 | 2 | 0 | 2 | 0 | 2 |
| (g) Receiver Noise Figure | [dB] | 5 | 5 | 5 | 5 | 5 | 5 |
| (h) Thermal Noise Density | [dBm/Hz] | -174 | -174 | -174 | -174 | -174 | -174 |
| (i) Receiver Interference Density | [dBm/Hz] | -Infty | -Infty | -Infty | -Infty | -Infty | -Infty |
| (j) total effective noise plus interfererence | [dBm/Hz] | -169 | -169 | -169 | -169 | -169 | -169 |
| (k)Information Rate (10 log (Rb)) | [dBHz] | 52.2 | 52.2 | 52.2 | 52.2 | 52.2 | 52.2 |
| | | 144[kbps] x (8/7) | | | | | |
| (l) Required Eb/(No+Io) with no power control | [dB] | | | 10.0 | 10.0 | 5.9 | 5.9 |
| | | including diversity gain | | | | | |
| (m) Receiver sensitivity = (j + k + l) | [dB] | | | -106.8 | -106.8 | -110.9 | -110.9 |
| (n) Hand-off gain | [dB] | 5.9 | 5.9 | 4.7 | 4.7 | 4.7 | 4.7 |
| (o) Explicit diversity gain | [dB] | 0 | 0 | 0 | 0 | 0 | 0 |
| | | included in req.Eb/No | | | | | |
| (o') Other gain | [dB] | 0 | 0 | 0 | 0 | 0 | 0 |
| (p) Log-normal fade margin | [dB] | 15.4 | 15.4 | 11.3 | 11.3 | 11.3 | 11.3 |
| (q) Maximum path loss = {d1-m+(e-f)+o+n+o' -p} | [dB] | | | 136.8 | 130.7 | 145.9 | 139.9 |
| (r) Maximum Range | [m] | | | 524 | 369 | 2965 | 2054 |

(O) L(R[m]) = 37 + 30log( R[m] ) [dB]
(P) L(R[km]) = 148.03 + 40log( R[km] ) [dB]
(V) L(R[km]) = 128.15 + 37.6log( R[km] ) [dB]

## *1.3 Link Budget LCD384*

| Test environment | | (O) | | (P) | | (V) | |
|---|---|---|---|---|---|---|---|
| Item | | Down Link | Up Link | Down Link | Up Link | Down Link | Up Link |
| Test service | | LC384 | LC384 | LC384 | LC384 | LC384 | LC384 |
| Ave. Tx Power per traffic Ch | [dBm] | 10.0 | 4.0 | 20.0 | 14.0 | 30.0 | 24.0 |
| (a1) Max Tx Power per traffic Ch | [dBm] | 10.6 | 4.6 | 20.6 | 14.6 | 30.6 | 24.6 |
| (a2) Max Total Tx Power | [dBm] | 10.6 | 4.6 | 20.6 | 14.6 | 30.6 | 24.6 |
| (b) Cable, connector, and combiner losses | [dB] | 2 | 0 | 2 | 0 | 2 | 0 |
| (c) Transmitter Antenna gain | [dBi] | 2 | 0 | 10 | 0 | 13 | 0 |
| (d1) Tx e.i.r.p. per traffic ch=(a1-b+c) | [dBm] | 10.6 | 4.6 | 28.6 | 14.6 | 41.6 | 24.6 |
| (d2) Total Tx e.i.r.p. = (a2-b+c) | [dBm] | 10.6 | 4.6 | 28.6 | 14.6 | 41.6 | 24.6 |
| (e) Receiver Antenna Gain | [dBi] | 0 | 2 | 0 | 10 | 0 | 13 |
| (f) Cable and Connector Losses | [dB] | 0 | 2 | 0 | 2 | 0 | 2 |
| (g) Receiver Noise Figure | [dB] | 5 | 5 | 5 | 5 | 5 | 5 |
| (h) Thermal Noise Density | [dBm/Hz] | -174 | -174 | -174 | -174 | -174 | -174 |
| (i) Receiver Interference Density | [dBm/Hz] | -Infty | -Infty | -Infty | -Infty | -Infty | -Infty |
| (j) total effective noise plus interfererence | [dBm/Hz] | -169 | -169 | -169 | -169 | -169 | -169 |
| (k)Information Rate (10 log (Rb)) | [dBHz] | 56.4 | 56.4 | 56.4 | 56.4 | 56.4 | 56.4 |
| | | 384 [kbps] x (8/7) | | | | | |
| (l) Required Eb/(No+Io) | [dB] | 11.3 | 11.3 | | | 5.8 | 5.8 |
| | | including diversity gain | | | | | |
| (m) Receiver sensitivity = (j + k + l) | [dB] | -101.3 | -101.3 | | | -106.8 | -106.8 |
| (n) Hand-off gain | [dB] | 5.9 | 5.9 | 4.7 | 4.7 | 4.7 | 4.7 |
| (o) Explicit diversity gain | [dB] | 0 | 0 | 0 | 0 | 0 | 0 |
| | | included in req.Eb/No | | | | | |
| (o') Other gain | [dB] | 0 | 0 | 0 | 0 | 0 | 0 |
| (p) Log-normal fade margin | [dB] | 15.4 | 15.4 | 11.3 | 11.3 | 11.3 | 11.3 |
| (q) Maximum path loss = {d1-m+(e-f)+o+n+o' -p} | [dB] | 102.4 | 96.4 | | | 141.8 | 135.8 |
| (r) Maximum Range | [m] | 151.4 | 95.5 | | | 2307 | 1598 |

(O) L(R[m]) = 37 + 30log( R[m] ) [dB]
(P) L(R[km]) = 148.03 + 40log( R[km] ) [dB]
(V) L(R[km]) = 128.15 + 37.6log( R[km] ) [dB]

## 1.4 Link Budget UDD144

| Test environment | | (O) | | (P) | | (V) | |
|---|---|---|---|---|---|---|---|
| Item | | Down Link | Up Link | Down Link | Up Link | Down Link | Up Link |
| Test service | | UD144 | UD144 | UD144 | UD144 | UD144 | UD144 |
| Ave. Tx Power per traffic Ch | [dBm] | 10.0 | 4.0 | 20.0 | 14.0 | 30.0 | 24.0 |
| (a1) Max Tx Power per traffic Ch | [dBm] | 10.6 | 4.6 | 20.6 | 14.6 | 30.6 | 24.6 |
| (a2) Max Total Tx Power | [dBm] | 10.6 | 4.6 | 20.6 | 14.6 | 30.6 | 24.6 |
| (b) Cable, connector, and combiner losses | [dB] | 2 | 0 | 2 | 0 | 2 | 0 |
| (c) Transmitter Antenna gain | [dBi] | 2 | 0 | 10 | 0 | 13 | 0 |
| (d1) Tx e.i.r.p. per traffic ch=(a1-b+c) | [dBm] | 10.6 | 4.6 | 28.6 | 14.6 | 41.6 | 24.6 |
| (d2) Total Tx e.i.r.p. = (a2-b+c) | [dBm] | 10.6 | 4.6 | 28.6 | 14.6 | 41.6 | 24.6 |
| (e) Receiver Antenna Gain | [dBi] | 0 | 2 | 0 | 10 | 0 | 13 |
| (f) Cable and Connector Losses | [dB] | 0 | 2 | 0 | 2 | 0 | 2 |
| (g) Receiver Noise Figure | [dB] | 5 | 5 | 5 | 5 | 5 | 5 |
| (h) Thermal Noise Density | [dBm/Hz] | -174 | -174 | -174 | -174 | -174 | -174 |
| (i) Receiver Interference Density | [dBm/Hz] | -Infty | -Infty | -Infty | -Infty | -Infty | -Infty |
| (j) total effective noise plus interfererence | [dBm/Hz] | -169 | -169 | -169 | -169 | -169 | -169 |
| (k)Information Rate (10 log (Rb)) | [dBHz] | 53.2 | 53.2 | 53.2 | 53.2 | 53.2 | 53.2 |
| | | 277.3 [kbps] x (3/4) | | | | | |
| (l) Required Eb/(No+Io) | [dB] | 7.0 | 7.0 | 7.8 | 7.8 | 5.2 | 5.2 |
| | | including diversity gain | | | | | |
| (m) Receiver sensitivity = (j + k + l) | [dB] | -108.8 | -108.8 | -108.0 | -108.0 | -110.6 | -110.6 |
| (n) Hand-off gain | [dB] | 5.9 | 5.9 | 4.7 | 4.7 | 4.7 | 4.7 |
| (o) Explicit diversity gain | [dB] | 0 | 0 | 0 | 0 | 0 | 0 |
| | | included in req.Eb/No | | | | | |
| (o') Other gain | [dB] | 0 | 0 | 0 | 0 | 0 | 0 |
| (p) Log-normal fade margin | [dB] | 15.4 | 15.4 | 11.3 | 11.3 | 11.3 | 11.3 |
| (q) Maximum path loss = {d1-m+(e-f)+o+n+o' -p} | [dB] | 109.9 | 103.9 | 130.0 | 124.0 | 145.6 | 139.6 |
| (r) Maximum Range | [m] | 269 | 170 | 350 | 250 | 2911 | 2016 |

(O) L(R[m]) = 37 + 30log( R[m] ) [dB]
(P) L(R[km]) = 148.03 + 40log( R[km] ) [dB]
(V) L(R[km]) = 128.15 + 37.6log( R[km] ) [dB]

## *1.5 Link Budget UDD384*

| Test environment | | (O) | | (P) | | (V) | |
|---|---|---|---|---|---|---|---|
| Item | | Down Link | Up Link | Down Link | Up Link | Down Link | Up Link |
| Test service | | UD384 | UD384 | UD384 | UD384 | UD384 | UD384 |
| Ave. Tx Power per traffic Ch | [dBm] | 10.0 | 4.0 | 20.0 | 14.0 | 30.0 | 24.0 |
| (a1) Max Tx Power per traffic Ch | [dBm] | 10.6 | 4.6 | 20.6 | 14.6 | 30.6 | 24.6 |
| (a2) Max Total Tx Power | [dBm] | 10.6 | 4.6 | 20.6 | 14.6 | 30.6 | 24.6 |
| (b) Cable, connector, and combiner losses | [dB] | 2 | 0 | 2 | 0 | 2 | 0 |
| (c) Transmitter Antenna gain | [dBi] | 2 | 0 | 10 | 0 | 13 | 0 |
| (d1) Tx e.i.r.p. per traffic ch=(a1-b+c) | [dBm] | 10.6 | 4.6 | 28.6 | 14.6 | 41.6 | 24.6 |
| (d2) Total Tx e.i.r.p. = (a2-b+c) | [dBm] | 10.6 | 4.6 | 28.6 | 14.6 | 41.6 | 24.6 |
| (e) Receiver Antenna Gain | [dBi] | 0 | 2 | 0 | 10 | 0 | 13 |
| (f) Cable and Connector Losses | [dB] | 0 | 2 | 0 | 2 | 0 | 2 |
| (g) Receiver Noise Figure | [dB] | 5 | 5 | 5 | 5 | 5 | 5 |
| (h) Thermal Noise Density | [dBm/Hz] | -174 | -174 | -174 | -174 | -174 | -174 |
| (i) Receiver Interference Density | [dBm/Hz] | -Infty | -Infty | -Infty | -Infty | -Infty | -Infty |
| (j) total effective noise plus interfererence | [dBm/Hz] | -169 | -169 | -169 | -169 | -169 | -169 |
| (k)Information Rate (10 log (Rb)) (k) | [dBHz] | 56.2 | 56.2 | 56.2 | 56.2 | 56.2 | 56.2 |
| | | 554.6 [kbps] x (3/4) | | | | | |
| (l) Required Eb/(No+Io) | [dB] | 7.0 | 7.0 | 7.8 | 7.8 | 5.2 | 5.2 |
| | | including diversity gain | | | | | |
| (m) Receiver sensitivity = (j + k + l) | [dB] | -111.8 | -111.8 | -111.0 | -111.0 | -113.6 | -113.6 |
| (n) Hand-off gain | [dB] | 5.9 | 5.9 | 4.7 | 4.7 | 4.7 | 4.7 |
| (o) Explicit diversity gain | [dB] | 0 | 0 | 0 | 0 | 0 | 0 |
| | | included in req.Eb/No | | | | | |
| (o') Other gain | [dB] | 0 | 0 | 0 | 0 | 0 | 0 |
| (p) Log-normal fade margin | [dB] | 15.4 | 15.4 | 11.3 | 11.3 | 11.3 | 11.3 |
| (q) Maximum path loss = {d1-m+(e-f)+o+n+o' -p} | [dB] | 106.9 | 100.9 | 127.0 | 121.0 | 142.6 | 136.6 |
| (r) Maximum Range | [m] | 214 | 135 | 298 | 211 | 2423 | 1677 |

(O) L(R[m]) = 37 + 30log( R[m] ) [dB]
(P) L(R[km]) = 148.03 + 40log( R[km] ) [dB]
(V) L(R[km]) = 128.15 + 37.6log( R[km] ) [dB]

## 1.6 Link Budget UDD2048

| Test environment | | (O) | | (P) | | (V) | |
|---|---|---|---|---|---|---|---|
| Item | | Down Link | Up Link | Down Link | Up Link | Down Link | Up Link |
| Test service | | U2048 | U2048 | U2048 | U2048 | U2048 | U2048 |
| Ave. Tx Power per traffic Ch | [dBm] | 10.0 | 4.0 | 20.0 | 14.0 | 30.0 | 24.0 |
| (a1) Max Tx Power per traffic Ch | [dBm] | 10.6 | 4.6 | 20.6 | 14.6 | 30.6 | 24.6 |
| (a2) Max Total Tx Power | [dBm] | 10.6 | 4.6 | 20.6 | 14.6 | 30.6 | 24.6 |
| (b) Cable, connector, and combiner losses | [dB] | 2 | 0 | 2 | 0 | 2 | 0 |
| (c) Transmitter Antenna gain | [dBi] | 2 | 0 | 10 | 0 | 13 | 0 |
| (d1) Tx e.i.r.p. per traffic ch=(a1-b+c) | [dBm] | 10.6 | 4.6 | 28.6 | 14.6 | 41.6 | 24.6 |
| (d2) Total Tx e.i.r.p. = (a2-b+c) | [dBm] | 10.6 | 4.6 | 28.6 | 14.6 | 41.6 | 24.6 |
| (e) Receiver Antenna Gain | [dBi] | 0 | 2 | 0 | 10 | 0 | 13 |
| (f) Cable and Connector Losses | [dB] | 0 | 2 | 0 | 2 | 0 | 2 |
| (g) Receiver Noise Figure | [dB] | 5 | 5 | 5 | 5 | 5 | 5 |
| (h) Thermal Noise Density | [dBm/Hz] | -174 | -174 | -174 | -174 | -174 | -174 |
| (i) Receiver Interference Density | [dBm/Hz] | -Infty | -Infty | -Infty | -Infty | -Infty | -Infty |
| (j) total effective noise plus interfererence | [dBm/Hz] | -169 | -169 | -169 | -169 | -169 | -169 |
| (k)Information Rate (10 log (Rb)) (k) | [dBHz] | 63.4 | 63.4 | 63.4 | 63.4 | 63.4 | 63.4 |
| | | 2.21 [Mbps] | | | | | |
| (l) Required Eb/(No+Io) | [dB] | 10.3 | 10.3 | 10.3 | 10.3 | | |
| | | including diversity gain | | | | | |
| (m) Receiver sensitivity = (j + k + l) | [dB] | -95.3 | -95.3 | -95.3 | -95.3 | | |
| (n) Hand-off gain | [dB] | 5.9 | 5.9 | 4.7 | 4.7 | 4.7 | 4.7 |
| (o) Explicit diversity gain | [dB] | 0 | 0 | 0 | 0 | 0 | 0 |
| | | included in req.Eb/No | | | | | |
| (o') Other gain | [dB] | 0 | 0 | 0 | 0 | 0 | 0 |
| (p) Log-normal fade margin | [dB] | 15.4 | 15.4 | 11.3 | 11.3 | 11.3 | 11.3 |
| (q) Maximum path loss = {d1-m+(e-f)+o+n+o' -p} | [dB] | 96.4 | 90.4 | 117.3 | 111.3 | | |
| (r) Maximum Range | [m] | 95.5 | 60.3 | 170 | 120 | | |

(O) L(R[m]) = 37 + 30log( R[m] ) [dB]
(P) L(R[km]) = 148.03 + 40log( R[km] ) [dB]
(V) L(R[km]) = 128.15 + 37.6log( R[km] ) [dB]

# 2. Technology Description Template

| | | | |
|---|---|---|---|
| A1.1 | Test environment support | | |
| A1.1.1 | In what test environments will the SRTT operate? | Office/Pedestrian/Vehicular | |
| A1.1.2 | If the SRTT supports more than one test environment, what test environment does this technology description template address? | Office/Pedestrian/Vehicular | |
| A1.1.3 | Does the SRTT include any features in support of FWA application? Provide detail about the impact of those features on the technical parameters provided in this template, stating whether the technical parameters provided apply for mobile as well as for FWA applications. | FWA is supported | |
| A1.2 | Technical parameters<br>Note: Parameters for both forward link and reverse link should be described separately, if necessary. | | |
| A1.2.1 | What is the minimum frequency band required to deploy the system (MHz)? | 3.2[MHz] = 1.6[MHz]*2(FDD) | |
| A1.2.2 | What is the duplex method: TDD or FDD? | FDD<br>TDD is supported | |
| A1.2.2.1 | What is the minimum up/down frequency separation for FDD? | [TBD ex. 30[MHz] ] | |
| A1.2.2.2 | What is requirement of transmit/receive isolation? Does the proposal require a duplexer in either the mobile station (MS) or BS? | MS using 1 time slots | Not Required |
| | | MS using multi time slots | Required |
| | | BS | Required |
| A1.2.3 | Does the SRTT allow asymmetric transmission to use the available spectrum? Characterize. | Asymmetric duplex duty of TDD<br>Asymmetric duplex band width og FDD | |
| A1.2.4 | What is the RF channel spacing (kHz)? In addition, does the SRTT use an interleaved frequency plan?<br>Note:...................................... | 100[kHz]<br>No interleave. | |
| A1.2.5 | What is the bandwidth per duplex RF channel (MHz) measured at the 3 dB down points? It is given by (bandwidth per RF channel) x (1 for TDD and 2 for FDD). Provide detail. | 200[kHz] | |
| A1.2.5.1 | Does the proposal offer multiple or variable RF channel bandwidth capability? If so, are multiple bandwidths or variable bandwidths provided for the purposes of compensating the transmission medium for impairments but intended to be feature transparent to the end user? | Yes. Variable bandwidth scheme named BDMA<br>BDMA is Band Division Multiple Access which use very wide band OFDM signal and share the block of sub-carriers ( 24 * 4.16[kHz] = 100[kHz] ) | |
| A1.2.6 | What is the RF channel bit rate (kbps)? | 159[kbps] /100[kHz] ( DQPSK )<br>2*(QPSK)*23 (24-1(differential) )/288.46[us]<br>239[kbps]/100[kHz] ( D8PSK ) | |
| | Note: The maximum modulation rate of RF (after channel encoding, adding of in-band control signalling and any overhead signalling) possible to transmit carrier over an RF channel, i.e. independent of access technology and of modulation schemes. | | |

| | | |
|---|---|---|
| A1.2.7 | Frame Structure: Describe the frame structure to give sufficient information such as: | |
| | - frame length | 1.15[ms] |
| | - the number of time slots per frame | 4[time slot/frame] |
| | - guard time or the number of guard bits | Tu=288.46[us/time slot]<br>Tm=240[us] for OFDM modulation length<br>Tg=48.46[us] for guard time |
| | - user information bit rate for each time slot | |
| | - channel bit rate (after channel coding) | |
| | - channel symbol rate (after modulation) | fsym = 1/Tu = 3.467[ksym/s] |
| | -associated control channel (ACCH) bit rate | |
| | - power control bit rate. | 2[bit/time slot] |
| | Note 1: Channel coding may include forward error correction (FEC), cyclic redundancy checking (CRC), ACCH, power control bits and guard bits. Provide detail.<br>Note 2: Describe the frame structure for forward link and reverse link, respectively.<br>Note 3: Describe the frame structure for each user information rate. | |
| A1.2.8 | Does the SRTT use frequency hopping?<br>If so, characterize and explain particularly the impact (e.g. improvements) on system performance. | Yes.<br>Frequency Diversity Effect.<br>Interference Diversity Effect.<br>Operation without FH is also possible e.g. DCA operation |
| A1.2.8.1 | What is the hopping rate? | 866.7[hop/sec]<br>(1 [hop/frame ) |
| A1.2.8.2 | What is the number of the hopping frequency sets? | Depend on Assigned frequency band<br>(ex. 200[frequency/20MHz] ) |
| A1.2.8.3 | Are BSs synchronised or non-synchronised? | Synchronisation is not required.<br>(preferred ) |
| A1.2.9 | Does the SRTT use a spreading scheme? | No. |
| A1.2.9.1 | What is the chip rate (Mchip/s)? Rate at input to modulator. | N/A |
| A1.2.9.2 | What is the processing gain? 10 log (Chip rate / Information rate). | N/A |
| A1.2.9.3 | Explain the uplink and downlink code structures and provide the details about the types (e.g. personal numbering (PN) code, Walsh code) and purposes (e.g. spreading, identification, etc.) of the codes. | N/A |
| A1.2.10 | Which access technology does the proposal use: TDMA, FDMA, CDMA, hybrid, or a new technology?<br>In the case of CDMA, which type of CDMA is used: Frequency Hopping (FH) or Direct Sequence (DS) or hybrid? Characterize. | Hybrid SFH-TDMA and BDMA(FDMA)<br>BDMA is Band Division Multiple Access which use very wide band OFDM signal and share the block of sub-carriers ( 24 * 4.16[kHz] =100[kHz] ) for each user. |
| A1.2.11 | What is the baseband modulation technique? If both the data modulation and spreading modulation are required, describe in detail. | Frequency Domain DPSK (DQPSK,D8PSK) |

| | | |
|---|---|---|
| | What is the peak to average power ratio after baseband filtering (dB)? | 10log( N )[dB]<br>N is number of sub-carriers |
| A1.2.12 | What are the channel coding (error handling) rate and form for both the forward and reverse links? | K=7,R=3/4-1/3 Convolutional encoding<br>Soft decision Viterbi Decoding<br>Reed-Solomon code for data ( R=0.8-0.9) |
| | E.g., does the SRTT adopt:<br>- FEC or other schemes?<br>- unequal error protection? Provide details.<br>- soft decision decoding or hard decision decoding? Provide details.<br>- iterative decoding (e.g. turbo codes)? Provide details.<br>- Other schemes? | |
| A1.2.13 | What is the bit interleaving scheme? Provide detailed description for both uplink and downlink. | 4.615[ms] data-frame data is encoded. 4 frame coded bits are buffered. 4 hopping burst is generated by using 4 frame coded bits.<br>As a result, 18.46[ms/interleave] or 16[hop/interleave] is achieved.<br>Longer interleave size is available |
| A1.2.14 | Describe the approach taken for the receivers (MS and BS) to cope with multipath propagation effects (e.g. via equaliser, RAKE receiver, etc.). | Not using equaliser or RAKE receiver<br>OFDM is robust against multipath propagation. |
| A1.2.14.1 | Describe the robustness to intersymbol interference and the specific delay spread profiles that are best or worst for the proposal. | ISI (inter symbol interference is very small using OFDM)<br>ITU TG8/1 Vehicular C ( rms delay spread 12[us], max delay is 55[us] ) |
| A1.2.14.2 | Can rapidly changing delay spread profile be accommodated? Describe. | Yes.<br>No impact. |
| A1.2.15 | What is the adjacent channel protection ratio?<br>Note: In order to maintain robustness to adjacent channel interference, the SRTT should have some receiver characteristics that can withstand higher power adjacent channel interference. Specify the maximum allowed relative level of adjacent RF channel power in dBc. Provide detail how this figure is assumed. | 10[dBc]<br>Adjacent channel spurious emission will be less than -17[dB] , and required C/I is more than 5[dB].<br>Basically, adjacent band signal will not exceed 0[dB], because all transmit signal should be power controlled. Moreover, -17[dB] is worst and rare case which occurs at when transmit power is maximum in power control operation. Frequency Hopping will provide risk diversity and it is also available to adjacent band interference. |
| A1.2.16 | Power classes | |
| A1.2.16.1 | Mobile terminal emitted power: What is the radiated antenna power measured at the antenna? For terrestrial component, give (in dBm). For satellite component, the mobile terminal emitted power should be given in e.i.r.p. (effective isotropic radiated power) (in dBm). | |
| A1.2.16.1.1 | What is the maximum peak power transmitted while in active or busy state? | OFDM signal has high peak.<br>Maximum peak transmit power is required 3[dB] higher than average power within the burst with allowable distortion. Burst average power is calculated by 4 times of time average power described in next section. |
| | | |
| | | |

| | | | |
|---|---|---|---|
| A1.2.16.1.2 | What is the time average power transmitted while in active or busy state? Provide detailed explanation used to calculate this time average power. | (O) | 4 [dBm] |
| | | (P) | 14 [dBm] |
| | | (V) | 24[dBm] |
| A1.2.16.2 | Base station transmit power per RF carrier for terrestrial component | | |
| A1.2.16.2.1 | What is the maximum peak transmitted power per RF carrier radiated from antenna? | OFDM signal has high peak.<br>Maximum peak transmit power is required 9[dB] higher than time average power described in next section with allowable distortion.<br>( BS will amplify all of users with one or several amplifiers) | |
| A1.2.16.2.2 | What is the average transmitted power per RF carrier radiated from antenna? | (O) | 10 [dBm] |
| | | (P) | 24 [dBm] |
| | | (V) | 30[dBm] |
| A1.2.17 | What is the maximum number of voice channels available per RF channel that can be supported at one BS with 1 RF channel (TDD systems) or 1 duplex RF channel pair (FDD systems), while still meeting ITU-T G.726 performance requirements? | 4 [voice channels/100kHz band slot] | |
| A1.2.18 | Variable bit rate capabilities: Describe the ways the proposal is able to handle variable baseband transmission rates. For example, does the SRTT use:<br>-adaptive source and channel coding as a function of RF signal quality?<br>-variable data rate as a function of user application?<br>-variable voice/data channel utilization as a function of traffic mix requirements?<br>Characterize how the bit rate modification is performed. In addition, what are the advantages of your system proposal associated with variable bit rate capabilities? | Multi time slot scheme ( from 1 to 4 time slots)<br>Multi band slot scheme ( Variable bandwidth transmmision)<br>( from 1 to whole of available band slot)<br>Multi coding rate.<br>Convolutional coding R=3/4-1/3<br>BCH for data | |
| A1.2.18.1 | What are the user information bit rates in each variable bit rate mode? | 11.5[kbps] ( 1 time slot x 1 band slot )<br>x[kbps] = N(time slot) * ( M(band slot ) * 23 - 3 )<br>* 16 / 18.46[ms] * 2 * R( coding rate) -<br>0.6[kbps](control channel)<br><br>Half or quarter rate is available | |
| A1.2.19 | What kind of voice coding scheme or CODEC is assumed to be used in proposed SRTT? If the existing specific voice coding scheme or CODEC is to be used, give the name of it. If a special voice coding scheme or CODEC (e.g. those not standardized in standardization bodies such as ITU) is indispensable for the proposed SRTT, provide detail, e.g. scheme, algorithm, coding rates, coding delays and the number of stochastic code books. | 8[kbps] is for normal<br>Supporting 4[kbps] is better.<br>Supporting 16[kbps], 32[kbps] is better | |
| A1.2.19.1 | Does the proposal offer multiple voice coding rate capability? Provide detail. | SRTT offers multiple voice coding rate capability | |

| | | | |
|---|---|---|---|
| A1.2.20 | Data services: Are there particular aspects of the proposed technologies which are applicable for the provision of circuit-switched, packet-switched or other data services like asymmetric data services? For each service class (A, B, C and D) a description of SRTT services should be provided, at least in terms of bit rate, delay and BER/frame error rate (FER). | | |
| | Note 1: See Recommendation ITU-R M.[FPLMTS.TMLG] for the definition of:<br>- "circuit transfer mode"<br>- "packet transfer mode"<br>- "connectionless service"<br>and for the aid of understanding "circuit switched" and "packet switched" data services.<br>Note 2: See ITU-T Recommendation I.362 for details about the service classes A, B, C and D. | | |
| A1.2.20.1 | For delay constrained, connection oriented. (Class A) | | |
| A1.2.20.2 | For delay constrained, connection oriented, variable bit rate (Class B) | | |
| A1.2.20.3 | For delay unconstrained, connection oriented. (Class C) | | |
| A1.2.20.4 | For delay unconstrained, connectionless. (Class D) | | |
| A1.2.21 | Simultaneous voice/data services: Is the proposal capable of providing multiple user services simultaneously with appropriate channel capacity assignment? | Yes. | |
| | | | |
| | Note: The following describes the different techniques that are inherent or improve to a great extent the technology described above to be presented.<br>Description for both BS and MS are required in attributes from A1.2.22 through A1.2.23.2. | | |
| | | | |
| A1.2.22 | Power control characteristics: Is a power control scheme included in the proposal? Characterize the impact (e.g. improvements) of supported power control schemes on system performance. | Yes.<br>Decrease power consumption of the terminal.<br>Decrease adjacent band interference.<br>Decrease co-channel interference to other communications.<br>Increase system capacity approximately twice. | |
| A1.2.22.1 | What is the power control step size in dB? | +1.0,0.0,-1.0[dB] | |
| A1.2.22.2 | What are the number of power control cycles per second? | every time burst.<br>866[control/s] | |
| A1.2.22.3 | What is the power control dynamic range in dB? | Up link | 80[dB] |
| | | Down link | 20[dB] |
| A1.2.22.4 | What is the minimum transmit power level with power control? | 20[nW] in up link | |
| A1.2.22.5 | What is the residual power variation after power control when SRTT is operating? Provide details about the circumstances (e.g. in terms of system characteristics, environment, deployment, MS-speed, etc.) under which this residual power variation appears and which impact it has on the system performance. | Standard deviation of variation which is approximated by log-normal distribution is few decibel.<br>Major impact on the system will not appear. | |
| A1.2.23 | Diversity combining in MS and BS: Are diversity combining schemes incorporated in the design of the SRTT? | Yes. | |

| | | |
|---|---|---|
| A1.2.23.1 | Describe the diversity techniques applied in the MS and at the BS, including micro diversity and macro diversity, characterizing the type of diversity used, for example: | Time diversity effect by 18.4[ms] interleaving<br>Frequency diversity effect by FH<br>2 branch antenna diversity |
| | -time diversity : repetition, RAKE-receiver, etc.,<br>- space diversity : multiple sectors, multiple satellite, etc.,<br>- frequency diversity : FH, wideband transmission, etc.,<br>- code diversity : multiple PN codes, multiple FH code, etc.,<br>- other scheme | |
| | Characterize the diversity combining algorithm, for example, switch diversity, maximal ratio combining, equal gain combining. Additionally, provide supporting values for the number of receivers (or demodulators) per cell per mobile user. State the dB of performance improvement introduced by the use of diversity.<br>For the MS: what is the minimum number of RF receivers (or demodulators) per mobile unit and what is the minimum number of antennas per mobile unit required for the purpose of diversity reception?<br>These numbers should be consistent to that assumed in the link budget template of Annex 2 and that assumed in the calculation of the "capacity" defined at A1.3.1.5. | Combining method of all diversity scheme is maximum ratio combining (MRC) at the input of Viterbi decoder.<br><br>2 branch space antenna diversity requires<br>2 antennas<br>2 receivers<br>2 demodulators<br>but demodulator will be reused for each branch of signal except memory ,Viterbi decoder and channel decoder require 1 unit respectively. |
| A1.2.23.2 | What is the degree of improvement expected in dB? Also indicate the assumed conditions such as BER and FER. | Total gain is 10[dB] including 3[dB] by 2 branch at BER=0.1[%]. |
| A1.2.24 | Handover/Automatic Radio Link Transfer (ALT): Do the radio transmission technologies support handover? | Yes. |
| | Characterize the type of handover strategy (or strategies) which may be supported, e.g. MS assisted handover. Give explanations on potential advantages, e.g. possible choice of handover algorithms. Provide evidence whenever possible. | Mobile Assisted Hand Over. |
| A1.2.24.1 | What is the break duration (sec) when a handover is executed? In this evaluation, a detailed description of the impact of the handover on the service performance should also be given. Explain how the estimate was derived. | 0[s]<br>Applying coded-bit level hand over through the MSC<br>Information bits are connected with each base station by coding and interleaving. |
| A1.2.24.2 | For the proposed SRTT, can handover cope with rapid decrease in signal strength (e.g. street corner effect)?Give a detailed description of | Basically, hand over will be detected not decreasing the received power at connecting base stations but increasing the received power at other base stations which are candidates for hand over.<br>MAHO will be effective to select the candidate base station for hand over. |
| | - the way the handover detected, initiated and executed, | Received signal strength will be detected and initiated by surrounding BS |
| | - how long each of this action lasts (minimum/maximum time in msec), | Under Investigation |
| | - the time-out periods for these actions. | TBD |

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| A1.2.25 | Characterize how the proposed SRTT reacts to the system deployment (e.g. necessity to add new cells and/or new carriers) particularly in terms of frequency planning. | Frequency planning is not required in1 frequency reuse or 3 sector frequency ( 1 site ) reuse.<br>N frequency reuse case, frequency planning is necessary. |
| A1.2.26 | Sharing frequency band capabilities: To what degree is the proposal able to deal with spectrum sharing among UMTS systems as well as with all other systems: | |
| | - spectrum sharing between operators | Use different band with adequate guard band between each operator's bands.<br>Guard band is 100[kHz] |
| | - spectrum sharing between terrestrial and satellite UMTS systems | Same as the above |
| | - spectrum sharing between UMTS and non-UMTS systems | same as the above. |
| | - spectrum sharing between private and public UMTS operator. | same as the above. |
| | - other sharing schemes. | |
| A1.2.27 | Dynamic channel allocation: Characterize the Dynamic Channel Allocation (DCA) schemes which may be supported and characterize their impact on system performance (e.g. in terms of adaptability to varying interference conditions, adaptability to varying traffic conditions, capability to avoid frequency planning, impact on the reuse distance, etc.). | In case of not applying FH, DCA is used. Detecting no interference frequency band and assign users to the band ,like DECT or PHS. |
| A1.2.28 | Mixed cell architecture: How well does the SRTT accommodate mixed cell architectures (pico, micro and macrocells)? Does the proposal provide pico, micro and macro cell user service in a single licensed spectrum assignment, with handoff as required between them? (terrestrial component only) | Using different frequency bands.<br>Hand over is possible. |
| | Note: Cell definitions are as follows:<br>pico - cell hex radius (r) < 100 m<br>micro - 100 m < (r) < 1000 m<br>macro - (r) > 1000 m | |
| A1.2.29 | Describe any battery saver / intermittent reception capability. | |
| A1.2.29.1 | Ability of the MS to conserve standby battery power: Provide details about how the proposal conserves standby battery power. | Intermittent reception can be possible. |
| A1.2.30 | Signalling transmission scheme: If the proposed system will use SRTTs for signalling transmission different from those for user data transmission, describe the details of the signalling transmission scheme over the radio interface between terminals and base (satellite) stations. | Using 2 time slots, because time alignment value is unknown before communicating between BS and MS |
| A1.2.30.1 | Describe the different signalling transfer schemes which may be supported, e.g. in connection with a call, outside a call. Does the SRTT support:<br>- new techniques? Characterize.<br>- signalling enhancements for the delivery of multimedia services? Characterize. | Basic formation of signal is same but reduce the information bits and ensure correct receiving. |

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| A1.2.31 | Does the SRTT support a Bandwidth on Demand (BOD) capability? BOD refers specifically to the ability of an end-user to request multi-bearer services. Typically, this is given as the capacity in the form of bits per second of throughput. Multi-bearer services can be implemented by using such technologies as multi-carrier, multi-time slot or multi-codes. If so, characterize these capabilities.<br>Note: BOD does not refer to the self-adaptive feature of the radio channel to cope with changes in the transmission quality (see A1.2.5.1). | If higher rate is demanded, more sub-carriers can be assigend.<br>Multi-time slot is also available |
| A1.2.32 | Does the SRTT support channel aggregation capability to achieve higher user bit rates? | Yes. BDMA scheme has no limit of system band width and user bit rate. ( If frequency resource and device are available) |
| A1.3 | Expected performances | |
| A1.3.1 | for terrestrial test environment only | |
| A1.3.1.1 | What is the achievable BER floor level (for voice)? | Almost 0[%] |
| | Note: The BER floor level is evaluated under the BER measuring conditions defined in Annex 2 using the data rates indicated in section 1 of Annex 2. | |
| A1.3.1.2 | What is the achievable BER floor level (for data)? | Almost 0[%] |
| | Note: The BER floor level is evaluated under the measuring conditions defined in Annex 2 using the data rates indicated in section 1 of Annex 2. | |
| A1.3.1.3 | What is the maximum tolerable delay spread (in nsec) to maintain the voice and data service quality requirements? | 12000[ns] ( Old ITU TG8/1 Vehicular C model) |
| | Note: The BER is an error floor level measured with the Doppler shift given in the BER measuring conditions of Annex 2. | |
| A1.3.1.4 | What is the maximum tolerable Doppler shift (in Hz) to maintain the voice and data service quality requirements? | At least 1000[Hz] |
| | Note: The BER is an error floor level measured with the delay spread given in the BER measuring conditions of Annex 2. | |
| A1.3.1.5 | Capacity: The capacity of the radio transmission technology has to be evaluated assuming the deployment models described in Annex 2 and technical parameters from A1.2.22 through A1.2.23.2. | |

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| A1.3.1.5.1 | What is the voice traffic capacity per cell (not per sector): Provide the total traffic that can be supported by a single cell in Erlangs/MHz/cell in a total available assigned non-contiguous bandwidth of 30 MHz (15 MHz forward/15 MHz reverse) for FDD mode or contiguous bandwidth of 30 MHz for TDD mode. Provide capacities for all penetration values defined in the deployment model for the test environment in Annex 2. The procedure to obtain this value is described in Annex 2. The capacity supported by not a standalone cell but a single cell within contiguous service area should be obtained here. | See system level simulation results |
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