| | | |
|---|---|---|
| A1.3.1.5.2 | What is the information capacity per cell (not per sector): Provide the total number of user-channel information bits which can be supported by a single cell in Mbps/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 |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| A1.3.1.6 | Does the SRTT support sectorization? If yes, provide for each sectorization scheme and the total number of user-channel information bits which can be supported by a single site in Mbps/MHz (and the number of sectors) in a total available assigned non-contiguous bandwidth of 30 MHz (15 MHz forward/15 MHz reverse) in FDD mode or contiguous bandwidth of 30 MHz in TDD mode. | Yes.<br>3 , 6 sectors per cell is effective to increase capacity |
| | | |
| | | |
| A1.3.1.7 | Coverage efficiency: The coverage efficiency of the radio transmission technology has to be evaluated assuming the deployment models described in Annex 2. | |
| A1.3.1.7.1 | What is the base site coverage efficiency in $km^2$/site for the lowest traffic loading in the voice only deployment model? Lowest traffic loading means the lowest penetration case described in Annex 2. | See Link budget Template |
| | | |
| | | |
| A1.3.1.7.2 | What is the base site coverage efficiency in $km^2$/site for the lowest traffic loading in the data only deployment model? Lowest traffic loading means the lowest penetration case described in Annex 2. | See Link budget Template |

| | | |
|---|---|---|
| | | |
| | | |
| A1.3.3 | Maximum user bit rate (for data): Specify the maximum user bit rate (kbps) available in the deployment models described in Annex 2. | At least 2048[kbps] |
| | | |
| | | |
| A1.3.4 | What is the maximum range in metres between a user terminal and a BS (prior to hand-off, relay, etc.) under nominal traffic loading and link impairments as defined in Annex 2? | See Link budget Template |
| | | |
| | | |
| A1.3.5 | Describe the capability for the use of repeaters. | Possible |
| A1.3.6 | Antenna Systems: Fully describe the antenna systems that can be used and/or have to be used; characterize their impacts on systems performance, (terrestrial only); | -Conventional antenna system<br>( 2 branch antenna diversity )<br>-Tx diversity antenna system is available<br>Each transmit burst is transmitted from different antenna which are placed like conventioal diversity antenna<br>-Switched beam antenna will be supported.<br>It improve link margin and capacity. |
| | e.g., does the SRTT have the capability for the use of:<br>- Remote antennas: Describe whether and how remote antenna systems can be used to extend coverage to low traffic density areas.<br>- Distributed antennas: Describe whether and how distributed antenna designs are used, and in which UMTS test environments.<br>- Smart antennas (e.g., switched beam, adaptive, etc.): Describe how smart antennas can be used and what is their impact on system performance.<br>- Other antenna systems. | |
| A1.3.7 | Delay (for voice) | |
| A1.3.7.1 | What is the radio transmission processing delay due to the overall process of channel coding, bit interleaving, framing, etc., not including source coding? | data is interleaved over 18.4[ms] |
| | This is given as transmitter delay from the input of the channel coder to the antenna plus the receiver delay from the antenna to the output of the channel decoder. Provide this information for each service being provided. In addition, a detailed description of how this parameter was calculated is required for both the uplink and the downlink. | |
| A1.3.7.2 | What is the total estimated round trip delay in msec to include both the processing delay, propagation delay (terrestrial only) and VOCODER delay? Give the estimated delay associated with each of the key attributes described in Figure 1 of Annex 3 that make up the total delay provided. | [Voice codec has not been defined yet] |
| A1.3.7.3 | Does the proposed SRTT need echo control? | [Voice codec has not been defined yet] |
| A1.3.9 | Description of the ability to sustain quality under certain extreme conditions. | |

| | | |
|---|---|---|
| A1.3.9.1 | System overload (terrestrial only): Characterize system behaviour and performance in such conditions for each test services in Annex 2, including potential impact on adjacent cells. Describe the effect on system performance in terms of blocking grade of service for the cases that the load on a particular cell is 125%, 150%, 175%, and 200% of full load. | Graceful degradation |
| | Also describe the effect of blocking on the immediate adjacent cells. Voice service is to be considered here. Full load means a traffic loading which results in 1% call blocking with the BER of $10^{-3}$ maintained. | Under Investigation |
| A1.3.9.2 | Hardware failures: Characterize system behaviour and performance in such conditions. Provide detailed explanation on any calculation. | Hardware failueres must be detected by MS itself.<br>If it is detected, MS must not transmit any more. |
| A1.3.9.3 | Interference immunity: Characterize system immunity or protection mechanisms against interference. What is the interference detection method? What is the interference avoidance method? | Narrow band interference can be erasured every Band slot( 100[kHz] )<br>frequency hopping can distribute risks caused by interference. |
| A1.3.10 | Characterize the adaptability of the proposed SRTT to different and/or time-varying conditions (e.g. propagation, traffic, etc.) that are not considered in the above attributes of the section A1.3. | Insensitive against different and/or time-varying conditions |

| | | |
|---|---|---|
| A1.4 | Technology design constraints | |
| A1.4.1 | Frequency stability: Provide transmission frequency stability (not oscillator stability) requirements of the carrier (include long term - 1 year - frequency stability requirements in ppm). | |
| A1.4.1.1 | For Base station transmission (terrestrial component only) | 0.02[ppm] |
| A1.4.1.2 | For Mobile station transmission | MS Tx sigbal should track receiving signal frequency ( 0.1[ppm] ) |
| A1.4.2 | Out-of-band and spurious emissions: Specify the expected levels of base or satellite and mobile transmitter emissions outside the operating channel, as a function of frequency offset. | See Evaluation Report |
| A1.4.3 | Synchronisation requirements: Describe SRTT's timing requirements, e.g. | |
| | - Is BS-to-BS or satellite land earth station (LES)-to-LES synchronisation required? Provide precise information, the type of synchronisation, i.e., synchronisation of carrier frequency, bit clock, spreading code or frame, and their accuracy. | Syncronization is not required but prefered for easier operation. |
| | - Is BS-to-network synchronisation required? (terrestrial only) | TBD |
| | - State short-term frequency and timing accuracy of BS (or LES) transmit signal. | TBD |
| | - State source of external system reference and the accuracy required, if used at BS (or LES) (for example: derived from wireline network, or GPS receiver). | Both wire line and GPS available for synchronous operation. |
| | - State free run accuracy of MS frequency and timing reference clock. | +-2[ppm] |
| | - State base-to-base bit time alignment requirement over a 24 hour period, in microseconds. | TBD |

| | | | |
|---|---|---|---|
| | -For private systems: Can multiple un-synchronized<br>systems coexist in the same environment? | Multiple un-synchronized systems can coexist | |
| A1.4.4 | Timing jitter: For BS (or LES) and MS give:<br>- the maximum jitter on the transmit signal,<br>- the maximum jitter tolerated on the received signal.<br>Timing jitter is defined as r.m.s. value of the time variance normalized by symbol duration. | MS<br>BS | T.B.D.[us] on the transmit signal, |
| | | | T.B.D.[us] tolerated on the received signal |
| A1.4.5 | Frequency synthesizer: What is the required step size, switched speed and frequency range of the frequency synthesizer of MSs? | Step size = 100[kHz] or 200[kHz]<br>switched speed = 288[us]<br>frequency range depends on system band width | |
| A1.4.6.1 | Describe the special requirements on the fixed networks for the handover procedure. Provide handover procedure to be employed in proposed SRTT in detail. | No | |
| A1.4.7 | Fixed network feature transparency | | |
| A1.4.7.1 | Which service(s) of the standard set of ISDN bearer services can the proposed SRTT pass to users without fixed network modification. | | |
| A1.4.8 | Characterize any radio resource control capabilities that exist for the provision of roaming between a private (e.g., closed user group) and a public IMT-UMTS operating environment. | | |
| A1.4.9 | Describe the estimated fixed signalling overhead (e.g., broadcast control channel, power control messaging). Express this information as a percentage of the spectrum which is used for fixed signalling. Provide detailed explanation on your calculations. | | |
| A1.4.10 | Characterize the linear and broadband transmitter requirements for BS and MS. (terrestrial only) | BS requires linear amplifier, and broadband transmitteris available.<br>MS requires almost linear amplifier<br>( Keeping 3[dB] output back off ) | |
| A1.4.11 | Are linear receivers required? Characterize the linearity requirements for the receivers for BS and MS. (terrestrial only) | Yes. Same as GSM | |
| A1.4.12 | Specify the required dynamic range of receiver. (terrestrial only) | 80[dB] | |

| | | | |
|---|---|---|---|
| A1.4.13 | What are the signal processing estimates for both the hand-portable and the BS?<br>- MOPS (Millions of Operations Per Second) value of parts processed by DSP<br>- gate counts excluding DSP<br>- ROM size requirements for DSP and gate counts in Kbytes<br>- RAM size requirements for DSP and gate counts in Kbytes | MS | In case of minimum bit rate 10[kbps]<br>Diversity Demodulator(including FFT)<br>⇨ 0.608[M complexMAC/s]<br>⇨ 128[complex word memory]<br>⇨ 8 [ROM]<br>⇨ K = 7 Viterbi decoder<br>Modulator(including FFT)<br>⇨ 0.134[M complexMAC/s]<br>⇨ 64[complex ord memory]<br>⇨ 8[ROM] |
| | | BS | almost same as MS |
| | Note 1: At a minimum the evaluation should review the signal processing estimates (MOPS, memory requirements, gate counts) required for demodulation, equalization, channel coding, error correction, diversity processing (including RAKE receivers), adaptive antenna array processing, modulation, A-D and D-A converters and multiplexing as well as some IF and baseband filtering. For new technologies, there may be additional or alternative requirements (such as FFTs etc.).<br>Note 2: The signal processing estimates should be declared with the estimated condition such as assumed services, user bit rate and etc. | | |
| A1.4.15 | Characterize the frequency planning requirements: | | |
| | - Frequency reuse pattern: given the required C/I and the proposed technologies, specify the frequency cell reuse pattern (e.g. 3-cell, 7-cell, etc.) and, for terrestrial systems, the sectorization schemes assumed; | req.C/I = 5[dB] with Interference diversity<br>1 frequency reuse with adequate system load<br>3 frequency reuse with full load.<br>9 frequency reuse for noise limited operation at low traffic and large cell. | |
| | | | |
| | | | |
| | - Characterize the frequency management between different cell layers; | by using different band | |
| | - Does the SRTT use an interleaved frequency plan? | No. | |
| | - Are there any frequency channels with particular planning requirements? | No. | |
| | -Can the SRTT support self planning technique? | Not required. | |
| | - All other relevant requirements. | Nothing | |
| | Note: The use of the second adjacent channel instead of the adjacent channel at a neighbouring cluster cell is called "interleaved frequency planning". If a proponent is going to employ an interleaved frequency plan, the proponent should state so in A1.2.4 and complete A1.2.15 with the protection ratio for both the adjacent and second adjacent channel. | | |
| A1.4.16 | Describe the capability of the proposed SRTT to facilitate the evolution of existing radio transmission technologies used in mobile telecommunication systems migrate toward this SRTT. Provide detail any impact and constraint on evolution. | This system can be implemented from minimum service ( e.g. voice) to high grade service gradually . Existing network can be used at the moment. | |

| | | |
|---|---|---|
| A1.4.16.1 | Does the SRTT support backwards compatibility into GSM/DCS in terms of easy dual mode terminal implementation , spectrum co-existence and handover between UMTS and GSM/DCS? | Time slot length is exactly half of GSM/DCS<br>frame length is exactly 1/8 of GSM/DCS<br>Channel spacing is exactly half of GSM/DCS<br>SRTT already has frequency hopping capability<br>This also enables MAHO between UMTS and GSM/DCS. |
| A1.4.17 | Are there any special requirements for base site implementation? Are there any features which simplify implementation of base sites? (terrestrial only) | No. |
| A1.5 | Information required for terrestrial link budget template<br>Proponents should fulfil the link budget template given in Table 1.3 of Annex 2 and answer the following questions. | |
| A1.5.1 | What is the BS noise figure (dB)? | See Link budget template |
| A1.5.2 | What is the MS noise figure (dB)? | |
| A1.5.3 | What is the BS antenna gain (dBi)? | |
| A1.5.4 | What is the MS antenna gain (dBi)? | |
| A1.5.5 | What is the cable, connector and combiner losses (dB)? | |
| A1.5.5 | What are the number of traffic channels per RF carrier? | |
| A1.5.6 | What is the SRTT operating point (BER/FER) for the required $E_b/N_o$ in the link budget template? | |
| A1.5.7 | What is the ratio of intra-sector interference to sum of intra-sector interference and inter-sector interference within a cell (dB)? | |
| A1.5.8 | What is the ratio of in-cell interference to total interference (dB)? | |
| A1.5.9 | What is the occupied bandwidth (99%) (Hz)? | |
| A1.5.10 | What is the information rate (dBHz)? | |

# OFDMA Evaluation Report

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

## Part 3

## OFDMA Concept – Frequently asked Questions (FAQ)

***Summary:***

This document describes details which were requested in many questions to the Beta Concept Group.

The covered areas are:

- SFH/TDMA operation performance versus doppler frequency
- SFH/TDMA operation performance versus hopping bandwidth
- Fast Fourier Transform (FFT/IFFT) complexity as main element of the OFDMA system
- Feasibility and importance of antenna diversity reception system in hand-portable Mobile Station
- Detailed Handover procedures
- Additional Information on Time and Frequency Synchronisation
- Power Amplifier Requirements
- Multiband Reception and Filter Requirements
- Frequency Hopping Feasibility

# Table of Contents

# 1. BER Performance versus Doppler Frequency

The SFH/TDMA operation (originally proposed BDMA system by SONY) achieves very good frequency diversity by means of frequency hopping and very good time diversity by interleaving and coding.
Both techniques will dramatically reduce the required received Eb/No and strongly improve link margin.
I order to investigate the performance of the OFDMA proposal in high speed scenarios we simulated the required received Eb/No versus the doppler frequency in link level simulations. Table 1 shows simulation parameters. Figure 1 shows the required Eb/No value versus B.E.R. and Figure 2 shows the maximum Doppler frequency versus the required Eb/No value to achieve the target B.E.R. of 10e-3.

Figure 2 clearly shows that the BDMA system with the selected parameters (guard time, subcarrier spacing, ...) has a good balance to achieve low required Eb/No values in the wide range of maximum Doppler frequencies. It is surprising that for very fast moving MS ( $f_D$=1000[Hz] , speed is 500[km/h] @2[GHz] ) the system can achieve a high quality transmission without special techniques (e.g. equalisation).

**Table 1: Simulation Parameter**

| | |
|---|---|
| Delay Model | Vehicular A |
| Antenna Diversity | 2 Branch |
| Hopping Bandwidth | 12.8[MHz] |
| Application | Speech ( 12kbps incl. overhead ) |
| Correlation between antennas | 0.0 |

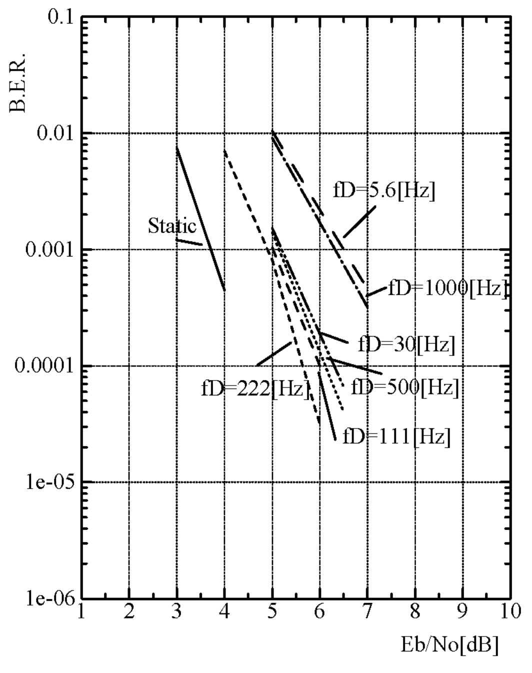



**Figure 1: B.E.R. versus speed (doppler) for speech service**

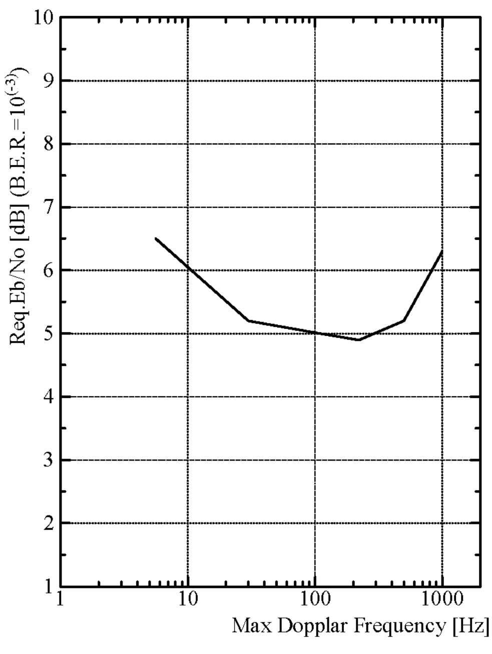



**Figure 2: Required $E_B/N_0$ versus speed (doppler frequency**

## 2. Hopping Bandwidth versus B.E.R.

The support of hirarchical cell structures is an important UMTS requirement. In this case each cell layer has a limited bandwidth.(e.g. 5[MHz] ). Originally the BDMA system achieves very good frequency diversity within higher bandwidths (e.g. 12.8[MHz] ). Now we simulated the transmission performance using a limited bandwidth to confirm the performance of frequency hopping.
Table 2 shows the used simulation parameters, Figure 4 shows the Eb/No versus B.E.R. for slow moving mobile station (MS) and fast moving MS. Figure 3 shows hopping bandwidth versus required Eb/No value to achieve a target B.E.R. of 10e-3.
This simulation confirmes that for fast moving MS the dominant factor of performance improvement is caused by the time diversity effect (time domain interleaving) and we cannot evaluate the effect of hopping bandwidth limitation. In case of slow moving MS the performance improves with wider hopping bandwidth.
It is also obvious that a bandwidth of 5[MHz] is already enough to achieve very low required Eb/No values (effect of frequency diversity).

**Table 2 Simulation Parameter**

| | |
|---|---|
| Delay Model | Vehicular A |
| Application | Speech ( 12kbps incl. overhead ) |
| Antenna Diversity | 2 Branch |
| Correlation between antennas | 0.0 |
| Max Doppler Frequency | 5.6[Hz] , 222[Hz] |

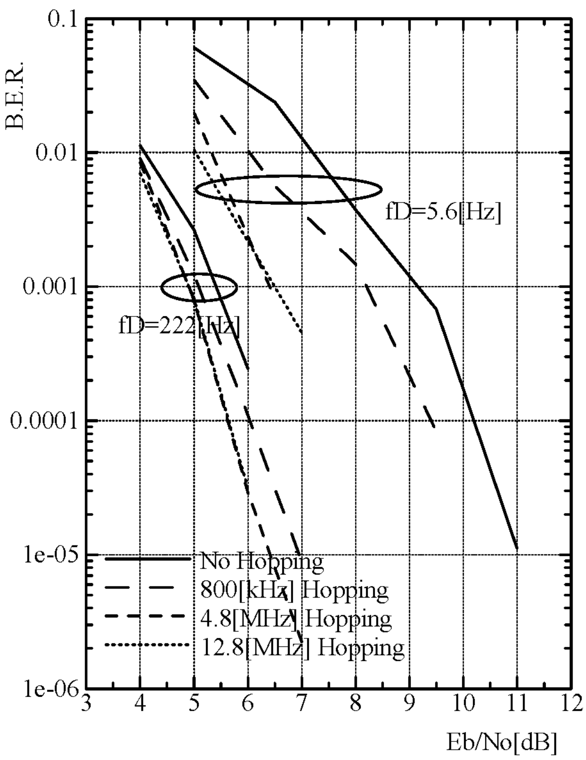



**Figure 4: BER versus $E_B/N_0$**

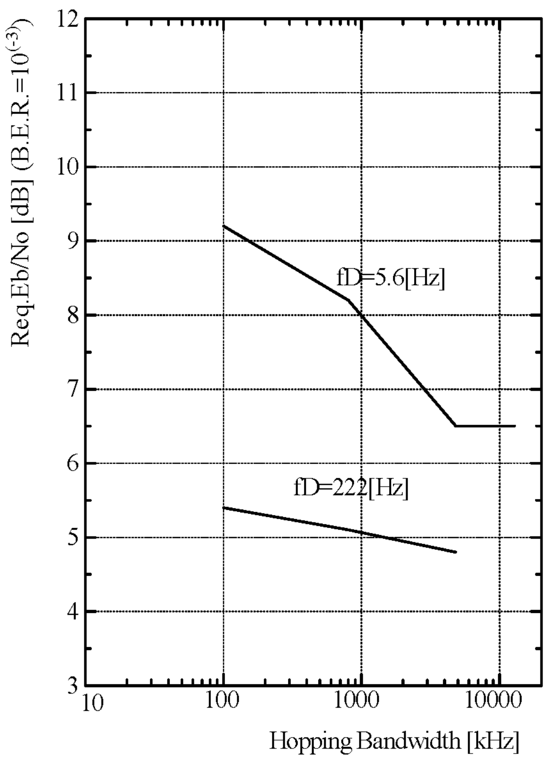



**Figure 3: Required $E_B/N_0$ versus Hopping Bandwidth**

# 3. OFDMA receiver complexity

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 [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) |

## Conclusions

It can be concluded that the complexity of the OFDMA depends upon the service required (almost linear complexity (MOPS) versus supported data rate). This offers benefits in terms of terminal cost and standby time for a given level of service. Even for the highest data rate service the complexity of the receiver is reasonable.

## References

[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*

# 4. Antenna Diversity Reception in hand-portable Mobile Station

It was often claimed that antenna diversity is not feasible and not effective (correlation) in a hand-portable mobile station (MS). In this report we will present information on the feasibility and effectivness of antenna diversity reception in a small (hand-held) MS.
We present actual field test measurement results to prove the simulations.

## Actual Measurement Result of Diversity Antennas of Mobile Station

SONY has much experience in the development of diversity antennas for hand-portable mobile stations (MS). As an example we present the measurement results for an PDC 1.5GHz handheld MS. The terminal TH241 for the PDC (Personal Digital Cellular) system was developed already 5 years ago. The following graph shows the layout.

The MS achieves antenna diversity by means of an conventional rod antenna and a second planar patch antenna (see Figure 5).

The used antenna diversity system for the hand-portable mobile station shows a good characteristics (low correlation) the measurement results (based on field test with the equipment) shows the effectivness.

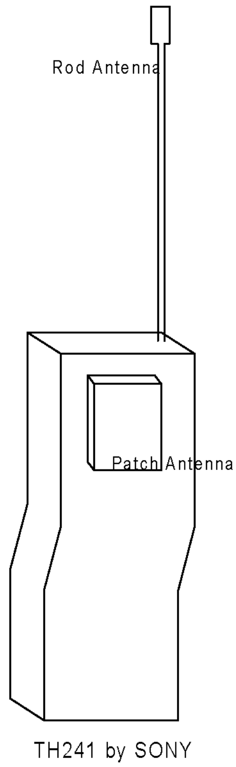



**Figure 5: TH 241 SONY PDC MS**

The following figures show the antenna pattern for both antennas.

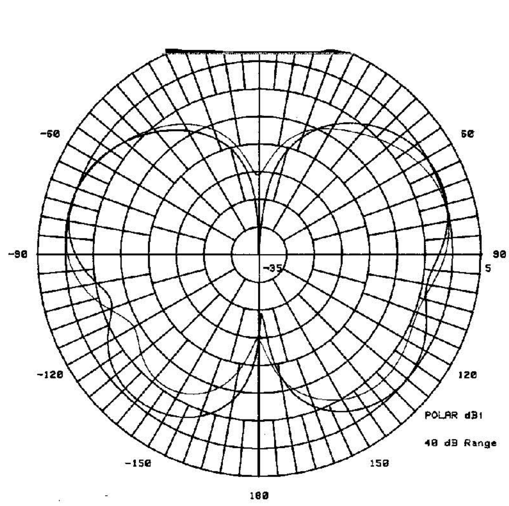



Figure 6: Antenna Pattern (Rod)

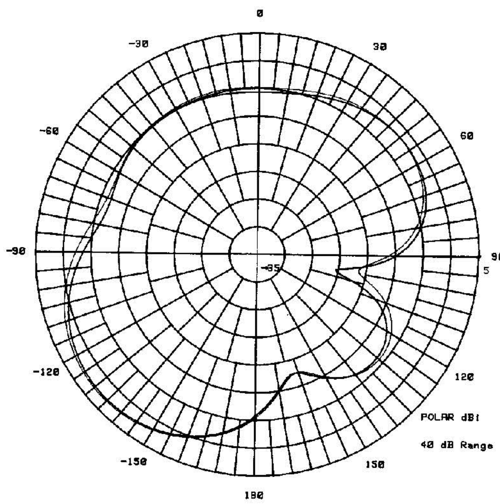



Figure 7: Antenna Pattern (Patch)

The RSSI versus time was measured for different vehicular speeds ( 10[km/h] and 80[km/h] respectively). The full line shows the RSSI of the Rod antenna and the dotted line is the RSSI of the Patch antenna (Figure 8 and Figure 9...).
It is obvious that both antennas have almost the same effective gain the correlation is very small.
The actual **measured correlation value is only 0.2!!** (see Table 3).

**Table 3: Measured Correlation Value for Antenna Diversity**

| Vehicular Speed | Correlation between antennas |
|---|---|
| 10[km/h] | 0.18 |
| 80[km/h] | 0.22 |

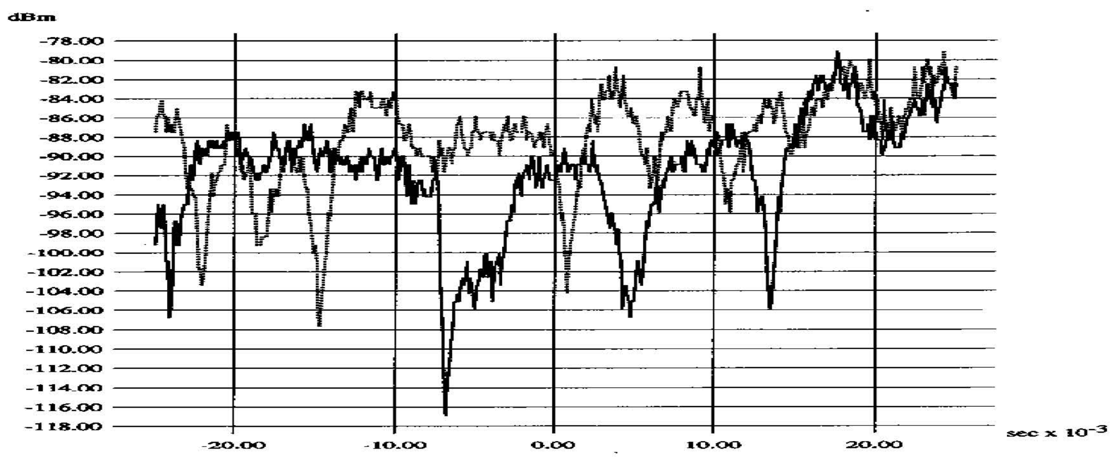



**Figure 8: RSSI of Both Antennas ( Vehicular speed = 80[km/h] )**

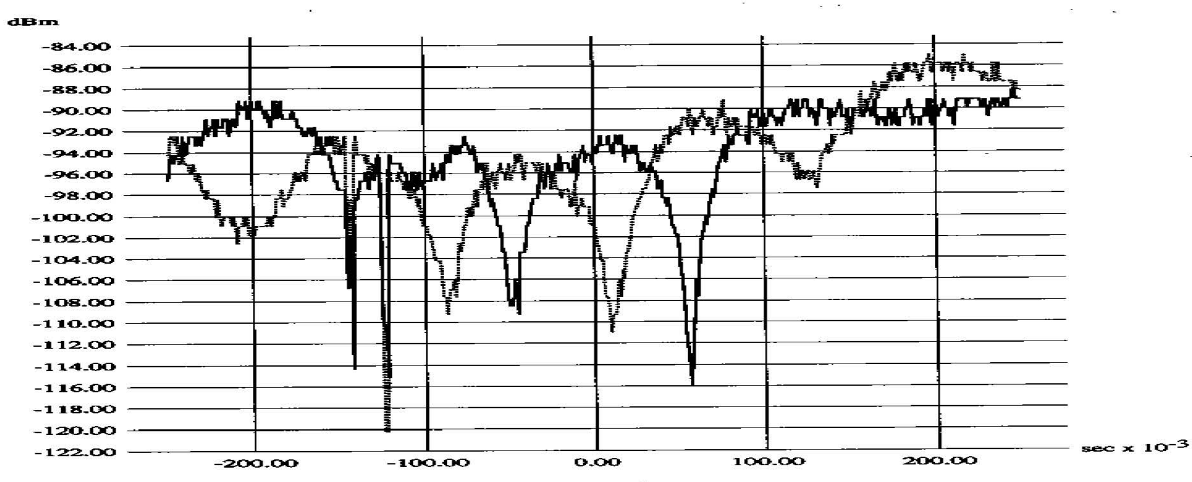



Figure 9: RSSI of Both Antennas ( Vehicular Speed = 10[km/h] )

## Importance of Antenna Diversity Reception

The basestation Tx power in typical operation can be larger compared to MS Tx power and this will achieve good results in the link budget. However, the capacity will not be improved by Tx power much because the capacity is mainly determined by the systems capability to accommodate co-channel interference.

As seen in the DS-CDMA results, the down link capacity is small. In general (g.e. for speech service) the same capacity is necessary both in up link and and down link. This means that the capacity of DS-CDMA is limited by the down link capacity.

Compared with OFDMA assuming the above mentioned realistic and very effective antenna diversity reception we believe the **capacity of the OFDMA system can be 3 times larger**.

**Table 4 Capacity Comparison**

| | |
|---|---|
| W-CDMA down link capacity in vehicular environment | 44[kbps/MHz/cell] |
| OFDMA down link capacity in vehicular environment | 122[kbps/MHz/Cell] |

## Comparison between with and without antenna diversity( Simulation )

To evaluate the perfromance with and without Rx antenna diversity the following simulation was carried out.

The simulation parameters are shown in Table 5, Figure 10 shows the B.E.R. versus $E_B/N_0$.

3.3dB improvement was achieved by the usage of an antenna diversity reception.

**Table 5: Simulation Parameter**

| | |
|---|---|
| Delay Model | Vehicular A |
| Max Doppler Spread | 222[Hz] |
| Application | Speech ( 12kbps incl. overhead ) |
| Correlation between antennas | 0.0 |

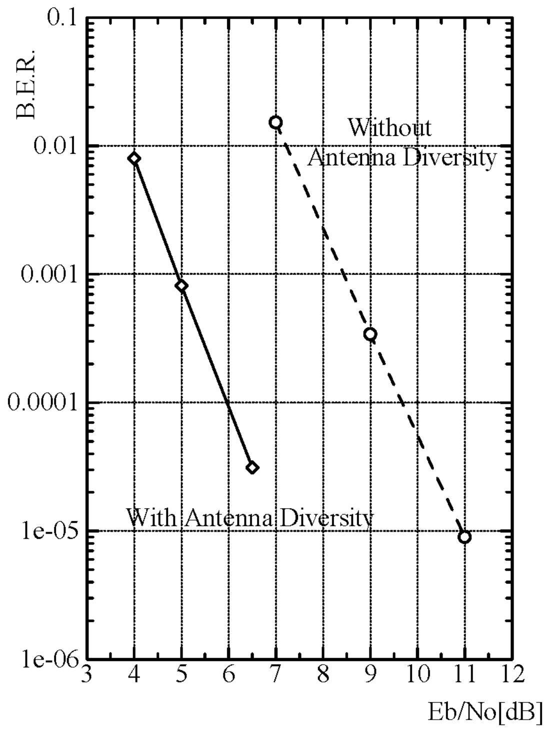



**Figure 10: B.E.R. vs $E_B/N_0$**

## Conclusion

Antenna diversity reception is very effective, realistic and be implemented at reasonable cost today.

There is no reason to remove it and for future high capacity systems (UMTS) we should make the best effort to develop even better antenna diversity reception systems as available now.

# 5. Hand Over Scheme of the OFDMA System

Handover is very important and the details should be presented. In this chapter we present the handover schemes we propose for the OFDMA system. This chapter contains information mainly related to the SFH/TDMA operation of the OFDMA based UTRA proposal.

## 5.1 Overview of Hand Over

The handover scheme of the OFDMA proposal is based on Base Station Originated Hand Over.

The following lines show the outline of the hand over procedure:

1. Mobile station (X) listens to the surrounding base stations. After identifying it reports the IDs of the nearest base stations (B,C,D..) to the connecting base station (A), this scheme is called Mobile Assisted Hand Over (MAHO)
2. BS-A asks BS-B,C,D… to observe MS-X (hopping pattern is reported to surrounding BS-B,C,D..
3. BS-B,C,D.. detect MS-X's receive signal strength (interference to BS-B,C,D,…).
4. If BS-B detects that MS-X's RSSI becomes higher than normal connecting user of BS-B, BS-B asks BS-A to hand over the MS-X. (Base Station Originated Hand Over)

## 5.2 Synchronisation

Synchronisation is not required in the BDMA system, however synchronisation provides many advantages in other aspects. Synchronisation can be provided by, for example, GPS system which is well known and adopted for many systems (even by the IS-95 DS-CDMA system).

### 5.2.1 Pseudo Synchronisation System

The following scheme is proposed in the non-synchronised BDMA system to achieve pseudo-synchronisation.

1. Each base station has enough precise timing reference ( e.g. 0.1[ppm], this means 1[μs] synchronisation slip will occur during 10[s] )
2. Propagation delay between BS-A and MS-X connected to BS-A ( Tpd(A,X) ) can be measured by their closed loop timing advance measurement/adjustment.
3. The Timing Difference (Framing) between the basestations BS-A and BS-B is assumed to be initially known ( D(A,B) ).
4. MS-X listens to IACH from BS-B and measures arrival time difference between BS-A and BS-B. Arrival time difference represents the time T = ( D(A,B)+Tpd(B,X)-Tpd(A,X) )
5. The system can estimate the propagation delay between BS-B and MS-X ( Tpd(B,X) = T - D(A,B) - Tpd(A,X) ) without te need for an activ traffic connection between BS-B and MS-X.
6. If MS-X is handed over to BS-B, the precise Tpd(B,X) can be measured and used to update the D(A,B)

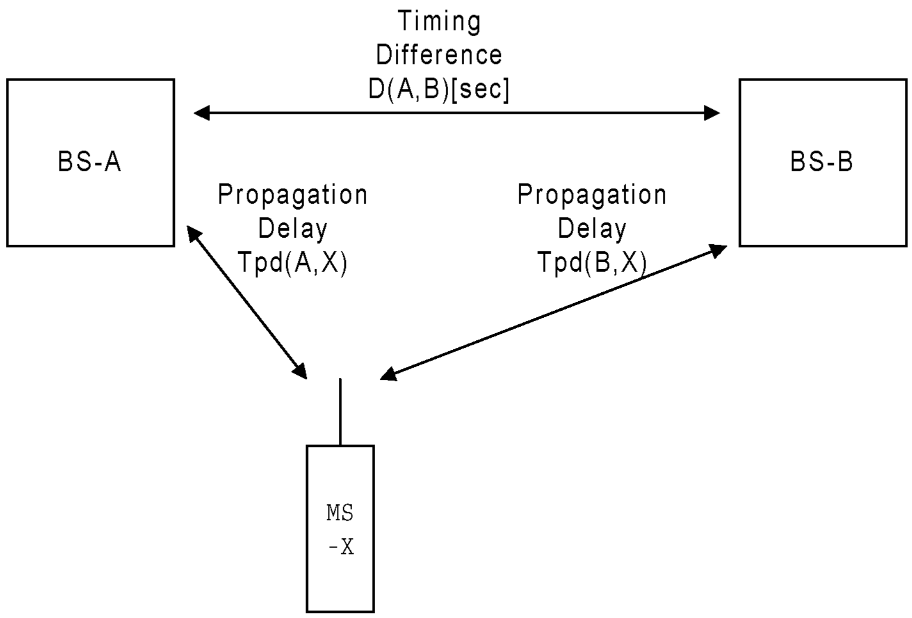



**Figure 11: Pseudo Synchronisation**

**Alternative method**
To measure the D(A,B), another possibility is to use a GPS receiver at each basestation. The GPS signal is used to measure the timing difference (framing) between the basetations. The difference is reported to each of the basestations but still the basestations are not synchronised.

### 5.2.2 Unsynchronised System

Completely non-sysnchronized system will be supported. When the mobile station performs a hand over the mobile station releases the previous connection and acquires the synchronisation of the new base station and connects.
This rough hand over scheme is not suitable for tight frequency reuse operation (e.g. 1 frequency reuse) and will cause some break duration.

## 5.3 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 basestations 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 the timeslot of the IACH comes which the MS wants to pick up the MS will puncture both Rx and Tx hop and uses 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 this will cause niglegible degradation.
5. The MS activates the KERO detector active and tries to decode the IACH.
6. When the MS detects and decoded the IACH, it reports back to its own, connecting BS about the succesfull detection of the IACH BS he detected the IACH.

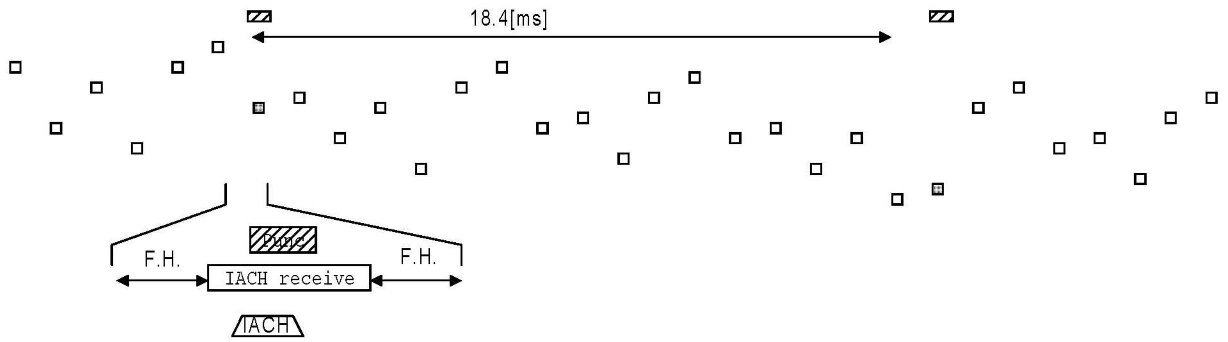



**Figure 12 Puncturing Scheme ( 1 of 4 time slot usage )**

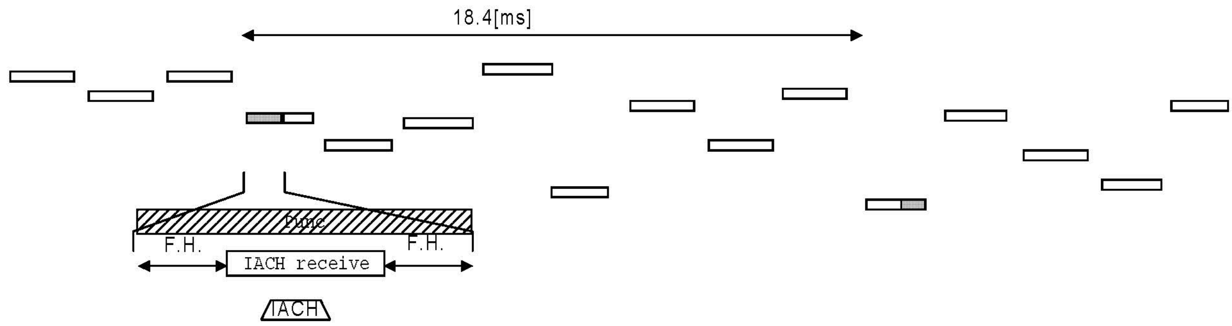



**Figure 13 Puncturing Scheme ( 7 of 8 time slot usage )**

## 5.4 Base Station Originated Hand Over

The following list shows the steps of a base station originated hand over.

1. When the MS (MS-X) connected to BS-A reports to the BS-A that it has detected the surrounding BS ( BS-B ),
2. BS-A asks BS-B to observe MS-X and inform BS-B about the hopping pattern of the MS-X.
3. BS-B sets its signal detector for detecting MS-X up link signal.
4. 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 basestations 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.
5. MS-X will receive BS-B's IACH to confirm the arrival time difference between BS-A and BS-B.
6. BS-B also measures the RSSI of MS-x's up link signal and compares the RSSI whith the RSSI of the MSs connected to BS-B (RSSIref).
7. When MS-X's RSSI exceed the RSSIref , BS-B asks BS-A to hand over MS-X.
8. BS-A informs MS-X to hand over to BS-B.

9. MS-X will change the connection from BS-A to BS-B.

## 5.5 Forward Hand Over

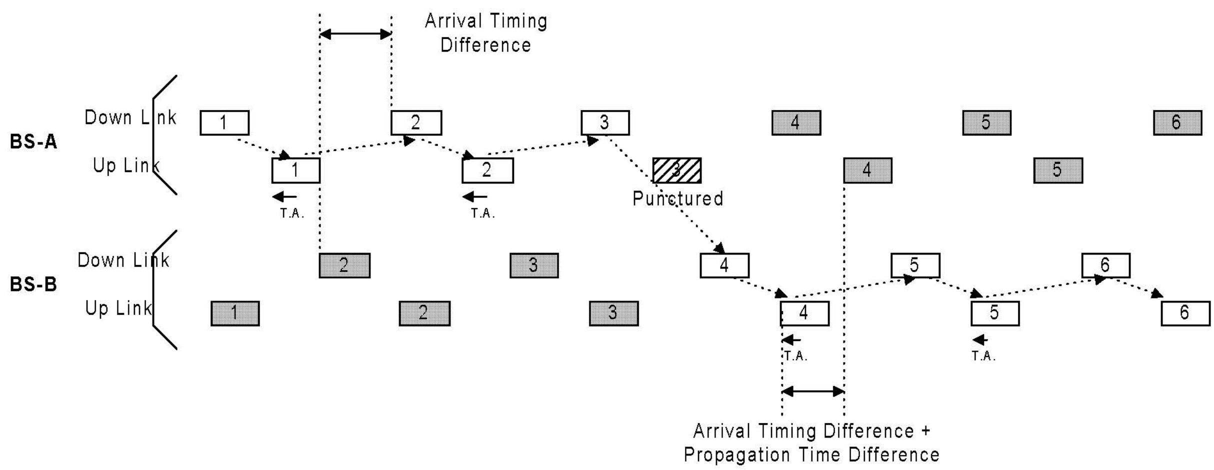
Forward hand over can be achieved easily.

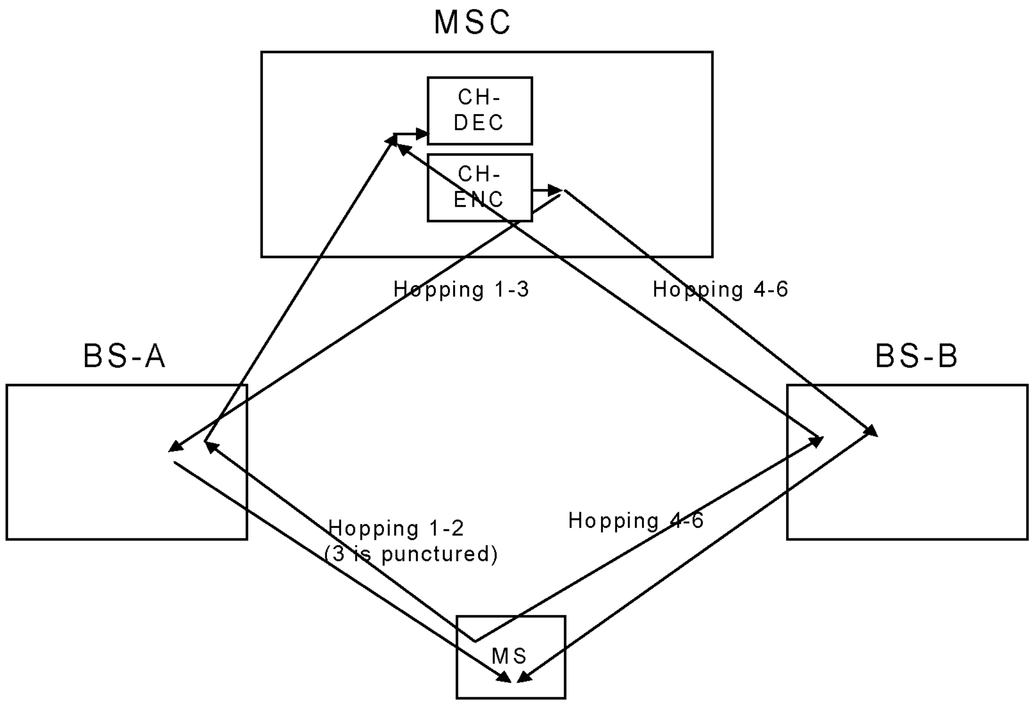
The following descripton is based on the assumption that MS-X is handed over from BS-A to BS-B.

- Even after the hand over, BS-A transmit 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-establishs the connection to MS-X.
- An alternative solution exists:
  If the network has enough capacity, The MSC can provide traffice 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.

## 5.6 MCS Initiated Hand Over

Seemless MCS initiated is supported even for unsynchronised basestations.
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 basestations and also to the target MS
The delivery of the down link data will be switched between the two basestations 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.




MSC
CH-
DEC
CH-
ENC
Hopping 1-3
Hopping 4-6
BS-A
BS-B
Hopping 1-2
(3 is punctured)
Hopping 4-6
MS

# 6. Time and Frequency Synchronisation

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:

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

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.*

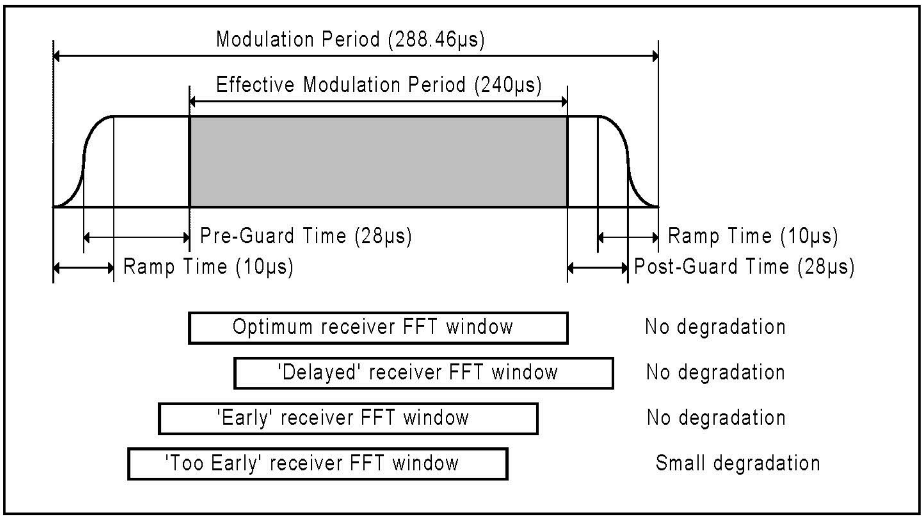



**Figure 14: OFMDA burst and synchronisation requirements**

# 7. Power Amplifier Requirements

The back-off requirement for larger number of subcarriers (e.g. 384 subcarriers for 1.6MHz operation) is the same as for small number of subcarriers as the statistics is the same. Further details can also be found in Tdoc B11/97 (Author: Lucent Technologies) which describes the effect of limiting the dynamic range of the OFDM signal to 3-5dB in order to reduce the out-of-band spurious emission and maintain a high power efficiency. The PA back-off is also independent from the modulation scheme (QPSK, 8PSK) and the interference detection schemes proposed (Random Phase Shift and Random Orthogonal Transform).

The adjacent channel interference is guaranteed to be below -17[dB] using readily available cheap MS power amplifiers with reasonable back-off (3dB). Comparing the adjacent channel interference with the co-channel interference level ( from -3[dB] to -5[dB] ), the adjacent channel interference which level is guaranteed to be below -17[dB] is negligible. Details can be found in the evaluation report, chapter 7.2 (SMG2 Tdoc 299/97).

Non-linear behavior of the PA is a really rare case in the OFDMA system and only happens if full power operation is required (e.g. Tx power is 30dBm), considering a uniform distribution of mobile stations within a cell only a very small number of MS (et the border of the cell) have to transmit at high power. In reality arround 80% (or more) of the MS operate in the linear region of the PA where OFDM with the proposed shaping (raised cosine ramping) shows an almost perfect rectangular spectrum shape.

Considering system operation the interference diversity is also very effective considering neighbouring bandslot interference.

The 3dB back-off mentioned in the evaluation report is referenced to the saturation output power (not 1dB compression point).

# 8. Multiband Reception and Filter Requirements

The multiband concept we propose does not imply the need for sharp cut-off filters at the IF in the MS.
Generally speaking the filter requirements are less tough as in already existing systems (we refer to IS-95). Some details can be presented:

- The downlink power dynamic range is limited to 17-20dB in the actual implementation. This helps to avoid too high power imbalance of the used bandslot compared to the two adjacent bandslots.
- Interference diversity is also very effective considering neighbouring bandslot interference.
- The mobile controls the average power of the received burst according to the target SIR for the actual communication. Therefore the power of the bursts is adjusted according to the average interference condition and the target SIR.
- Small oversampling (already used for the FFT/IFFT operation) allows relaxed filter shape specifications. An example is given for better understanding. For reference also the filtering requirements of IS-95 are given which are much more severe and can be implemented cheap already today.

For the presented OFDMA example we use 24 subcarriers per bandslot, the minimum FFT required to process 24 subcarriers is 32. This implies an oversampling ratio of (32/24)=1.33 of the ADC before delivery of the samples to the FFT unit. The oversampling also reduces the cut-off requirements of the analogue filtering before ADC.

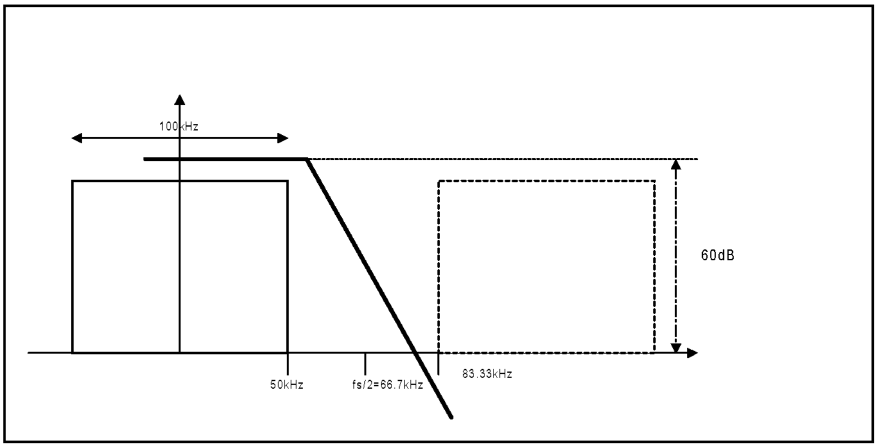



**Figure 15: OFDMA filter requirements**

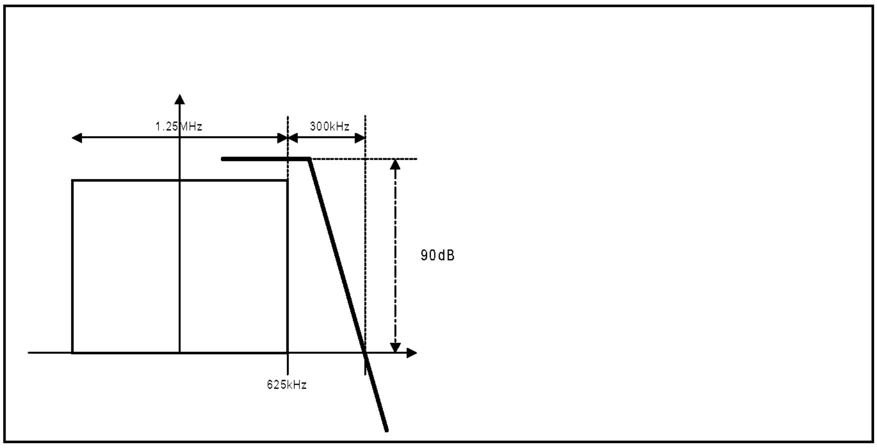



**Figure 16: IS-95 filter requirements (for reference)**

# 9. Frequency Hopping Feasibility

The OFDMA uses 4 time faster hopping than GSM. We present an example for speech.
For speech a 4-TDMA scheme is used, this scheme still allows simple implementation of the hopping synthesiser (acquisition time, frequency stepping, phase noise, spurious, ....).

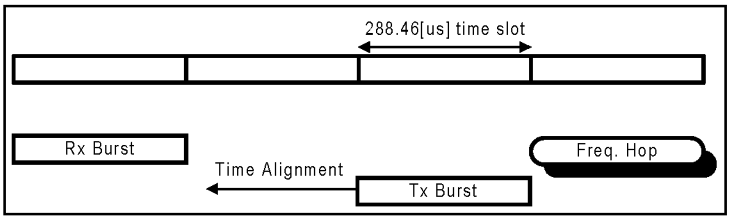



**Figure 17: 4-TDMA frame and frequency hopping**

In the 4-TDMA still 288µs are available for achieving the frequency hopping with accurate tuning and settling.
Actual hardware measurements using available synthesisers (g.e. fractional-N synthesisers) shows enough performance to support the 4-times faster hopping as compared to GSM.

Also within ACTS hopping synthesisers are developed to achieve very promising figures (e.g. 25µs acquisition time, 1kHz frequency stepping), actually developed prototype HW achieves already 80µs acquisition time and meets 1kHz frequency stepping and other *requirements (see ACTS 97 proceedings, Aarlborg, Denmark, pg.459-463, 'A High Resolution Synthesizer for SW Radio', W. Rebenak, D. Peris, Thomson-CSF Communications*).

## Number of required hopping synthesizers

At least for single timeslot operation (4-TDMA) and for multiple bandslot operation schemes using a single timeslot (e.g. 8 bandslots and 16 bandslots) only one frequency synthesiser is necessary to generate the frequency hopping. Especially speech (using single timeslot and single bandslot) and low rate data terminals (e.g. supporting LCD64 using multiple bandslots) can be implemented at low cost with a single synthesiser.
For higher data rate transmission reception and transmission is needed at the same time (e.g. using 7 timeslots in a 8-TDMA scheme) and two independent synthesisers are necessary for the reception and transmission. But for higher data rates a higher complexity of the MS should be allowed.
Only for clarification, the proposed RX diversity scheme is not correlated to the usage of multiple frequency synthesisers.

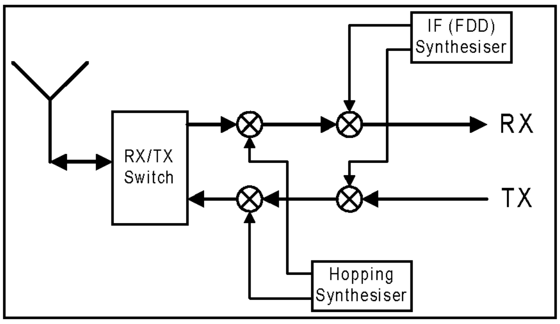



**Figure 19: Simple (low data rate) Rx/Tx layout with one hopping synthesiser**

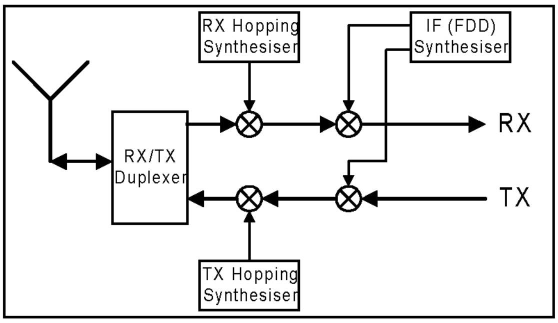



**Figure 18: Advanced (high data rate) Rx/Tx layout with two hopping synthesiser**

# Annex C:

# Concept Group Gamma $\gamma$ - Wideband TDMA (WB-TDMA)

**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 900 / 97

Madrid, Spain Agenda item 4.1: UTRA

December 15-19, 1997

Source: SMG2

# Concept Group Gamma -

# WB-TDMA:

# System Description Summary

**Concept Group Gamma: System Description Summary**

## 1 Introduction

The WB-TDMA concept described here constitutes a candidate Radio Transmission Technology (RTT) which includes the physical carrier structure, the radio dependent protocol layers from layer 1 to layer 3 as well as the related radio resource management algorithms. The flexibility and efficiency is provided by sophisticated multiple access means, which include adaptive mechanisms to optimise the performance of the physical layer. Further, it is not the efficient protocols or the physical layer techniques alone, which will provide an advanced radio transmission solution, rather the complete radio interface including effective radio resource management algorithms. These aspects have been fully considered as part of the work of the Gamma concept group.

The present document summarises the main system features. More detailed information can be found in the Gamma Group Evaluation Document (ETSI SMG2#24, Tdoc SMG2 365/97).

## 2 Key Technical Characteristics of the Basic System

| **Main MA parameters** | **WB-TDMA** |
|---|---|
| Multiple access method | TDMA |
| Duplexing method | FDD and TDD |
| Channel spacing | 1.6 MHz |
| Carrier bit rate | 2.6 Mbit/s / 5.2 Mbit/s |
| **Physical layer structure** | |
| Time slot structure | 16 or 64 slots/TDMA frame |
| Frame length | 4.615 ms |
| Multirate concept | Multislot |
| FEC codes | Rate Compatible Punctured Convolutional codes, Turbo Codes, Reed Solomon codes |
| ARQ scheme | Type II hybrid ARQ |
| Interleaving | Inter-slot and intra-slot interleaving |
| Modulation | B-OQAM / Q-OQAM |
| Pulse shaping | Root Raised Cosine, roll-off = 0.35 |

| | |
|---|---|
| Detection | Coherent, based on midamble |

## 3 Performance Enhancing Features

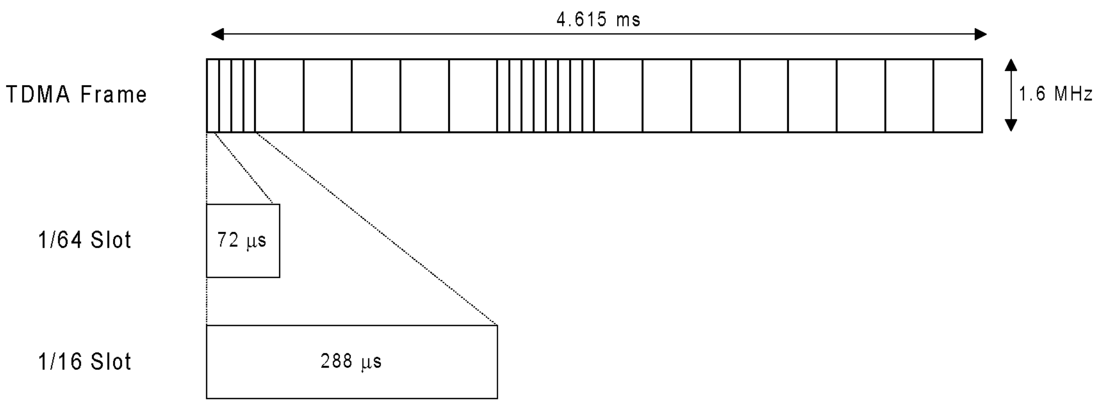
| Feature | Description | Comments |
|---|---|---|
| Frequency diversity | Frequency hopping per frame or slot | Also provides interference diversity |
| Time diversity | Time hopping within frame | Provides interference diversity without increasing total bandwidth |
| Path diversity | Antenna diversity | BS antenna diversity assumed<br><br>MS antenna diversity expected for high rate terminals. |
| Burst structure | Additional burst formats | Multiplexed burst for downlink efficiency<br><br>Bursts optimised for specific conditions (eg large delay spreads) |
| Modulation | Flexible modulation format | Any modulation/coding scheme meeting emission mask (including OFDM) can be used within a flexible burst structure |
| Bandwidth | Multi-band structure | Supports larger cells (narrow band) or higher bit rates (wide band) |
| Power control | Slow power control | 50 dB dynamic range<br><br>Fast power control could be used if frequency hopping is not viable (eg single carrier) |
| Handover | Mobile assisted hard handover | Inter-frequency handover supported<br><br>Soft handover (i.e. two simultaneous connections) is possible |
| Interference cancellation | Joint detection | Optional feature suited to suppression of small number of dominant interferers |
| Interference reduction | Directional antennas | Cell sectorisation is supported<br><br>Adaptive antenna techniques could be applied. |
| Channel allocation | Slow and fast DCA supported | Allows interference avoidance |

The features in the above table are not essential to the operation of WB-TDMA, but are generally considered highly desirable.

In addition, Link Adaptation in response to changes in channel conditions is considered essential for achieving high spectral efficiency.

# 4 System Description

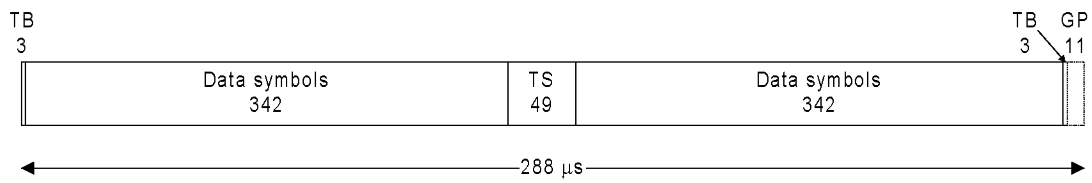
The frame duration is chosen to be 4.615ms for compatibility with GSM. A similar multi-frame structure to GSM could also be adopted.




**FDD frame structure of WB-TDMA.**

The frame is divided into slots of relative size 1/16 and 1/64. The same frame duration is applied in both FDD and TDD modes, except that in TDD mode an adjustable switching point determines the fraction of capacity devoted to uplink and downlink.

A number of different transmission bursts are defined for WB-TDMA. As an example, the diagram below shows a data burst for a 1/16th slot.



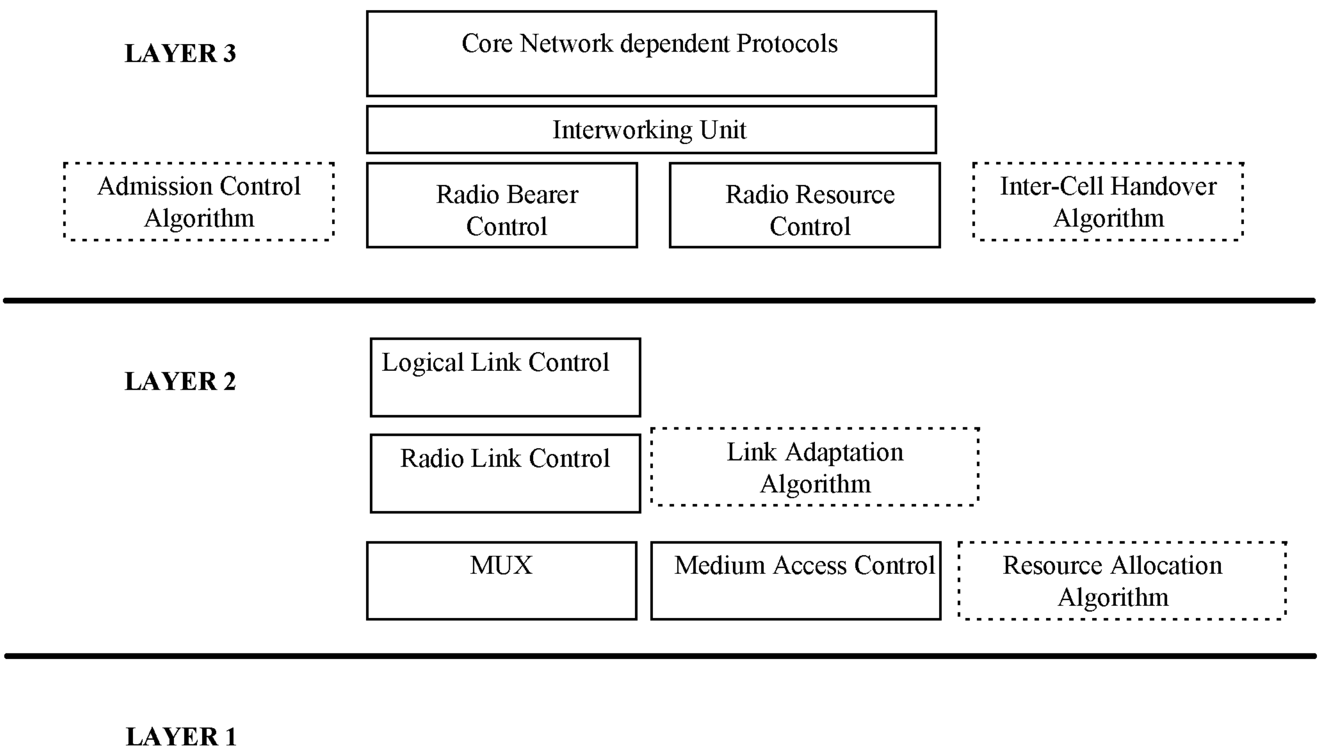

**Data burst structure. TB=tail symbols, TS=training sequence and GP= guard period.**

The basic modulation scheme is Binary Offset Quadrature Amplitude Modulation (B-OQAM) with a symbol rate of 2.6Msymbols/s. For higher bit rates Quaternary-OQAM is used. The corresponding carrier spacing is 1.6MHz.

Different user bit rates can be achieved by allocating different numbers of slots.

**Examples of service mappings for WB-TDMA**

| Required user bit rate (kbits/s) | Code rate | Slot type | Burst type | Modulation | Number of basic physical channels per frame |
|---|---|---|---|---|---|
| 8 | 0.5 | 1/64 | Nonspread Speech 2 | BOQAM | 0.5 |
| 64 | 0.5 | 1/64 | Nonspread Speech 2 | BOQAM | 4 |
| 144 | 0.5 | 1/16 | Nonspread Data | BOQAM | 2 |
| 384 | 0.5 | 1/16 | Nonspread Data | BOQAM | 5 |
| 1024 | 0.5 | 1/16 | Nonspread Data | BOQAM | 14 |
| 2048 | 0.5 | 1/16 | Nonspread Data | QOQAM | 14 |




**WB-TDMA Radio interface Protocols**

The above diagram represents the layer structure and the protocols and algorithms of the WB-TDMA radio interface. Algorithms are represented in dashed boxes. For example, link adaptation is applied in response to different channel conditions by adjusting the code rate, making it possible to achieve a given quality of service independently of the C/I.

## 5 Summary

The WB-TDMA concept has been developed as a cost-effective flexible platform for implementation of the UTRA, which can easily adapt to a variety of operating environments and application requirements. It offers a high degree of backwards compatibility with GSM, while at the same time is “future proof” because it allows enhancement by application of technological developments. WB-TDMA could also be used in combination with other techniques, for example as a complement to CDMA for provision of high bit rates over short ranges.

ETSI SMG#24 TDoc SMG 901 / 97

Madrid, Spain Agenda item 4.1: UTRA

December 15-19, 1997

Source: SMG2

# Concept Group Gamma -

# WB-TDMA:

# Evaluation Summary

**Concept Group Gamma: Evaluation Summary**

# 1 Introduction

The performance of the WB-TDMA concept has been evaluated in detail within the Gamma group. Results of link level and system level spectrum efficiency simulations are given in the Gamma Group Evaluation Document (ETSI SMG2#24, Tdoc SMG2 365/97). This also contains in Annex the Technologies Description Template, answers to questions from operators, and analytical results for spectrum efficiency.

Specific aspects which have been considered in the development of the WB-TDMA concept are:

- Support of high bit rates with a relatively simple terminal
- Effective support of non-real-time traffic with fast variations in data rate and packet size
- Support of TDD mode with data rates fulfilling the UMTS requirements
- Possibility to implement simple low bit rate terminals
- Narrow spectrum and low interference to adjacent carriers
- Flexibility for introduction of enhancements

# 2 Fulfilment of the High Level Requirements

This section describes how the WB-TDMA concept meets the High Level Requirements for UTRA.

## 2.1 Bearer capabilities

### 2.1.1 Maximum user bit rate

- **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 1500km/h with 1/64 slot bursts). The maximum cell size depends on propagation conditions, but is comparable with GSM at 1800MHz (assuming similar requirements for bearer capabilities and quality of service).

- **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

The maximum practical bit rate which can be provided depends on factors such as the operating environment, required quality of service, traffic loading and proximity of the mobile to the base station. However, the radio interface can support rates up to around 1Mbps for Rural and Suburban Outdoor, and 4Mbps over short ranges.

#### 2.1.1.1 Bearer Service Attributes

The WB-TDMA concept can provide bearers 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.

### 2.1.2 Flexibility

The WB-TDMA concept provides flexibility of bearer service attributes by use of a number of different transmission bursts optimised for different bit rates in different radio environments. The Link Adaptation mechanism can be used to dynamically maintain the quality of the connection under changes in propagation and interference conditions by adjusting transmission format and number of 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 capacity allocation. Scheduling of bearers is allowed, but could be the subject of further study. The bearer service attributes can be configured as required on initiation of a service, and changed dynamically if required.

#### 2.1.2.1. Minimum bearer capabilities

Bearers optimised for speech are supported in all operating environments. The BER requirements for RT data services are met by concatenated coding. The transmission delay depends on the interleaving depth, but the minimum value can be less than 20ms (one way). Packet delivery times of the order of 150ms can be provided (using Type II soft combining ARQ). The detailed performance trade-offs between delay and BER (via choice of modulation, coding and interleaving) require further study.

#### 2.1.2.2 Service traffic parameters

Since WB-TDMA provides Link Adaptation as a fundamental feature it can support the use of UMTS in various environments with a range of traffic densities range and a variety of traffic mixes in an economical way.

#### 2.1.2.3 Performance

Details of performance are given in the Gamma Group evaluation document:

### 2.1.3 Configuration management

WB-TDMA will allow the definition of configuration management features.

### 2.1.4 Evolution and modularity

The WB-TDMA concept is service independent, and is defined so that UMTS can be implemented in phases with enhancements for increasing functionality (for example making use of different modulation and coding technology). The requirement for backwards compatibility can be met by provision of a negotiation mechanism to agree on supported capabilities between mobiles and infrastructure. The WB-TDMA concept is consistent with the requirements of an open modular architecture and implementation of software downloading of radio interface features. However these aspects require further development.

### 2.1.5 Handover

#### 2.1.5.1 Overall handover requirements

Efficient seamless (mobile assisted) handovers can be provided in networks with synchronised base stations and between TDD and FDD systems. Seamless handover between unsynchronised systems is for further study. The signalling load arising from handovers is dependent on scenario, but is not expected to be significant. The level of security is not affected by handovers. Handover to second generation systems can be well supported by use of an idle frame allowing measurements of signal strengths from alternative base stations. The choice of frame structure allows synchronisation of UTRA with GSM sharing the same cell sites which simplifies handover in this case.

#### 2.1.5.2 Handover requirements with respect to the radio operating environments

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

## 2.2 Operational requirements

### 2.2.1 Compatibility with services provided by present core networks

Flexible RT and NRT bearers with a range of bit rates etc., allow current core network services to be supported.

### 2.2.2 Operating environments

WB-TDMA 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. WB-TDMA can support fixed wireless access, but performance in this application is for further study.

#### 2.2.2.1 Support of multiple radio operating environments

WB-TDMA can support the requirements of all the specified radio operating environments.

#### 2.2.2.2 Support of multiple equipment vendors

Minimum specification levels to ensure inter-operability are for further study.

### 2.2.3 Radio Access network planning

The Interference Averaging feature means that network planning is not as sensitive as in GSM. Link Adaptation ensures that minimal C/I planning is required. DCA can be used to re-configure the use of assigned frequency blocks in response to changing traffic. UMTS terminals using WB-TDMA will almost certainly incorporate frequency agility capability to support frequency hopping. This could facilitate the use over non-overlapping allocations across regions or countries (unless other hardware restrictions apply).

### 2.2.4 Public, Private and residential operators

#### 2.2.4.1 Public UMTS operators

The ability to guarantee pre-determined levels of quality for public operators is likely to require separate frequency allocations for each operator.

#### 2.2.4.2 Private UMTS operators

WB-TDMA is inherently resistant to interference and therefore is suitable for uncoordinated deployment. The Bunch concept allows installation of base-station clusters without any cell planning or co-ordination with other Bunches and co-ordination is automatically provided within a Bunch. DCA can further be used to avoid interference.

#### 2.2.4.3 Residential UMTS operators

Residential systems can be deployed in the same way as private systems.

## 2.3 Efficient spectrum usage

### 2.3.1 Spectral Efficiency

High spectral efficiency is achieved, and is better than GSM for comparable services. More detailed results are given in the Gamma Group evaluation document.

### 2.3.2 Variable asymmetry of total band usage

In an unpaired frequency allocation, TDD provides flexibility by adapting the uplink/downlink duty cycle. With paired frequency allocation, asymmetric traffic with pure FDD is likely lead to under utilisation of one or other of the band pairs. In this case TDD in the under used band would be an efficient solution.

### 2.3.3 Spectrum utilisation

WB-TDMA can be deployed using for some applications using a single 1.6MHz carrier (e.g. isolated cell). A small network could be deployed in as little as 5MHz. The concept is not critically sensitive to choice of carrier frequency.

### 2.3.4 Coverage/capacity

#### 2.3.4.1 Development and implementation risk

The WB-TDMA concept is a natural extension to proven technology (i.e. GSM) so unknown factors in development and implementation risks are minimised.

#### 2.3.4.2 Flexibility of radio network design

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

#### 2.3.4.3 Synchronisation

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

#### 2.3.4.4 Repeaters and relays

Repeaters and vehicles with mobile BS can be supported in principle, but the details are for further study.

### 2.3.5 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.

### 2.3.6 Evolution requirements

#### 2.3.6.1 Coverage evolution

The WB-TDMA concept supports:

- contiguous coverage (traditional cellular approach);
- island coverage (Bunch concept);
- spot coverage (isolated cell).

Since performance is not sensitive to base station deployment, a minimum of planning is required in order to install new cells to extend system coverage. Initial calculations indicate that since maximum range can be comparable to GSM at 1800MHz, reusing existing cell-sites is possible to achieve fast roll-out.

#### 2.3.6.2 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. WB-TDMA supports techniques for capacity improvement, such as the use of adaptive antenna, but these are not essential.

## 2.4 Complexity / cost

### 2.4.1 Mobile Terminal viability

WB-TDMA is not inherently complex. Low bit rate terminals will not require a duplexer. Low complexity equaliser techniques (eg DFE) are viable in low delay spread environments. Simulation studies show that frequency hopping combined with channel coding allow operation with high delay spreads.

### 2.4.2 Network complexity and cost

WB-TDMA provides a single radio interface concept which can be adapted to all operating environments. All the operating options within WB-TDMA are based on a common approach, in order to minimise implementation complexity. A layered approaches is has been followed in the development of the radio interface.

### 2.4.3 Mobile station types

Low cost terminals with a restricted set of functionality can be implemented. For example, limited bit rate, power output or multipath equalisation capability could be appropriate for private cordless telephone applications. Low rate terminals can operate without the need for duplex filters.

## 2.5 Requirements from bodies outside SMG

### 2.5.1 Alignment with IMT 2000

WB-TDMA meets at the technical requirements for submission as a candidate technology for IMT 2000 (FPLMTS) for all the terrestrial operating environments.

### 2.5.2 Minimum bandwidth allocation

WB-TDMA can be deployed using for some applications using a single 1.6MHz carrier (e.g. isolated cell). A small network could be deployed in as little as 5MHz (excluding guard bands). However, larger bandwidths will be required to achieve good trunking efficiency for high bit rate services.

### 2.5.3 Electromagnetic compatibility

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

#### 2.5.4 RF Radiation effects

WB-TDMA can operate at RF emission power levels which are in line with the recommendations related to electromagnetic radiation. For ease of implementation, a maximum transmitter output power of around 1W peak is considered desirable for hand portable units.

#### 2.5.5 Security

WB-TDMA should be able to accommodate at least the same level of protection as GSM..

#### 2.5.6 Co-existence with other systems

WB-TDMA is not inherently sensitive to co- or adjacent channel interference. It also does not produce high levels of adjacent channel interference. The exact guard band requirements depend on the deployment assumptions, but with a 1.6MHz signal bandwidth, are not large.

### 2.6 Multimode terminal capability

WB-TDMA shares aspects of TDMA with GSM, including related frame structures. This is beneficial for implementation of dual mode terminals.

### 2.7 Services supported by the radio interface

Detailed mechanisms for support of user position location are for further study.

**ETSI SMG**
**Meeting no 24**
**Madrid, Spain**
**15 - 19 December 1997**

**Tdoc SMG 902/97**

**Title: Wideband TDMA Evaluation Document v 3.0**

**Source: SMG2**

# Concept Group Gamma - Wideband TDMA

# EVALUATION DOCUMENT

v 3.0

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.

# Executive Summary

Concept group Gamma was set up to define a Wideband TDMA based concept as a proposal for UTRA. The outcome of the definition and evaluation is presented in this document.

The WB-TDMA concept described hereafter constitutes a candidate Radio Transmission Technology (RTT) covering the physical carrier structure, the radio dependent protocol layers from layer 1 to layer 3 as well as the related radio resource management algorithms. The flexibility and efficiency of the WB-TDMA based radio interface is provided with the sophisticated multiple access means, which include variable mechanisms to get efficiency out of the physical layer. Further on, it is not the efficient protocols or the physical layer techniques alone, which will provide advanced radio transmission solutions. Rather it is the complete radio interface with effective protocols, flexible physical structure and effective radio resource management algorithms that will provide the platform of the Radio Transmission Technology.

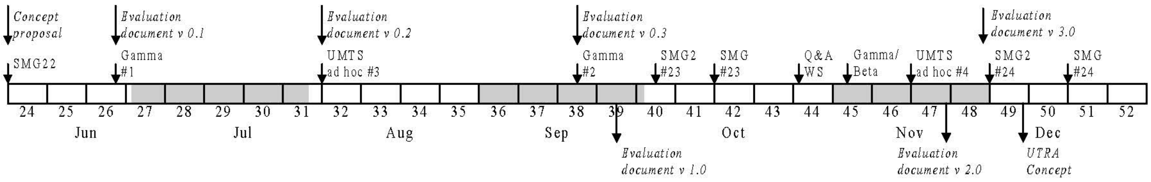



*Figure 1-1* Gamma group evaluation document time schedule

Gamma group has followed in its work open and progressive approach (*Figure* 1-1). Participation in the concept groups work and technical contributions have been received from major manufacturers in Europe: Alcatel, Frames project (Ericsson, Nokia, Siemens), Motorola and Philips as well as from France Télécom. Group has held three meetings and met during SMG2 and SMG2 UMTS ad hoc meetings.

The basic building blocks for the concept are described in detail in the following documents:

Layer 1 - WB-TDMA Evaluation document v 3.0 - Tdoc SGM2 365/97 (This document)
Layer 2 - Radio Protocols for WB-TDMA - Tdoc SMG2 Gamma 19/97
RRM - Radio Resource Management for WB-TDMA - Tdoc SMG2 Gamma 15/97

These documents give quite detailed picture of the concept. Further work is needed to provide detailed description of items that are still on generic level in these documents.

The evaluation work is presented also in this document in form of link and system level simulation results. The studied cases are listed in Table 1.

*Table 1 Evaluated services*

| Priority | Environment | Service mixture | Propagation model | Cell coverage | Link level | System level |
|---|---|---|---|---|---|---|
| **1.1**<br>**1.2**<br>**1.3**<br>**1.5**<br>extra | **Outdoor to Indoor and Pedestrian 3 km/h** | **UDD 384**<br>**Speech**<br>**LCD 144 kbit/s**<br>**UDD 2048**<br>UDD 144 | **Outdoor to Indoor and Pedestrian A** | **Microcell** | **completed**<br>**completed**<br>**completed**<br>**completed**<br>completed | **completed**<br>**completed**<br>(not required)<br>(not required) |
| **2.1**<br>**2.2**<br>**2.3**<br>**2.4**<br>extra<br>extra<br>extra | **Indoor 3 km/h** | **UDD 2048**<br>**Speech**<br>**LCD 384 kbit/s**<br>**50 % speech + 50 % UDD 384**<br>UDD 2048 with walls<br>UDD 144<br>UDD 384 | **Indoor A** | **Picocell** | **completed**<br>**completed**<br>**completed**<br>(not required)<br>(not required)<br>completed<br>completed | **completed**<br>(not required)<br>(not required)<br>**preliminary**<br>completed |
| **3.1**<br>**3.2**<br>**3.3**<br>extra<br>extra | **Vehicular 120 km/h** | **UDD 144**<br>**Speech**<br>**LCD 384 kbit/s**<br>UDD 384<br>UDD 2048 | **Vehicular A** | **Macrocell** | **completed**<br>**completed**<br>**completed**<br>completed<br>completed | (not required)<br>completed<br>completed |
| extra<br>extra<br>extra | Vehicular 120 km/h | Speech<br>UDD 144<br>UDD 384 | Vehicular B | | completed<br>completed<br>completed | (not req) |

| | | | | | | |
|---|---|---|---|---|---|---|
| **4**<br>extra<br>extra | **Vehicular**<br>**250 km/h** | **Speech**<br>UDD 144<br>UDD 384 | **Vehicular B** | | **completed**<br>completed<br>completed | (not req) |

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## Glossary of abbreviations used in:

| | |
|---|---|
| AC | Admission Control |
| ARQ | Automatic Repeat reQuest |
| BS | Base station |
| (D)CA | (Dynamic) Channel Allocation |
| DL | Downlink (forward link) |
| TDMA | Time Division Multiple Access |
| FDD | Frequency Division Duplexing |
| FEC | Forward Error Correction |
| FH | Frequency Hopping |
| FMA | Frames Multiple Access |
| HCS | Hierarchical Cell Structure |
| HO | Handover |
| IA | Interference Averaging |
| JD | Joint Detection |
| LA | Link Adaptation |
| LC | Load Control |
| Mbps | Mega bits per second |
| MS | Mobile Station |
| NRT | Non Real Time |
| PC | Power Control |
| QL | Quality Loop |
| RNC | Radio Network Controller |
| RRM | Radio Resource Management |
| RT | Real Time |
| TDD | Time Division Duplexing |
| TH | Time Hopping |
| TX | transmission |
| UL | Uplink (reverse link) |

# 1. Introduction

Concept group Gamma was set up to define a Wideband TDMA based concept as a proposal for UTRA. The current outcome of the definition and evaluation is presented in this document.

## *1.1 Contents*

In chapters 2 - 5 this document describes the WB-TDMA concept basic building blocks.Chapter 2 introduces the different logical channels and Chapter 3 the physical channels (layer 1). Further, the Logical Link Control (LLC), Radio Link Control (RLC) and Medium Access Control (MAC) are described in Chapter 4. Chapter 5 describes Radio Resource Management (RRM), the radio resource related part of the management plane.

Most of this document describes and evaluates the very basic WB-TDMA. However, there are several attractive and innovative possibilities foreseen to enhance the performance of the scheme. The Chapter 6 will describe some ideas about the possible enhancements.

Evaluation of the concept is based on extensive simulation campaign. Simulations have been completed and the results of these link and system level simulations are reported in chapter 7.

An essential part of any concept is its capability to fulfil the High Level Requirements set by ETSI SMG2. Chapter 8 discusses the presented concept and compares it to the high level requirements. Conclusions are presented in chapter 9.

## *1.2 Layered structure of the Radio Interface*

The WB-TDMA building blocks described in chapter 3 - 5 can be reviewed with the help of the layered structure of the Radio Interface shown in *Figure* 1-1 below.

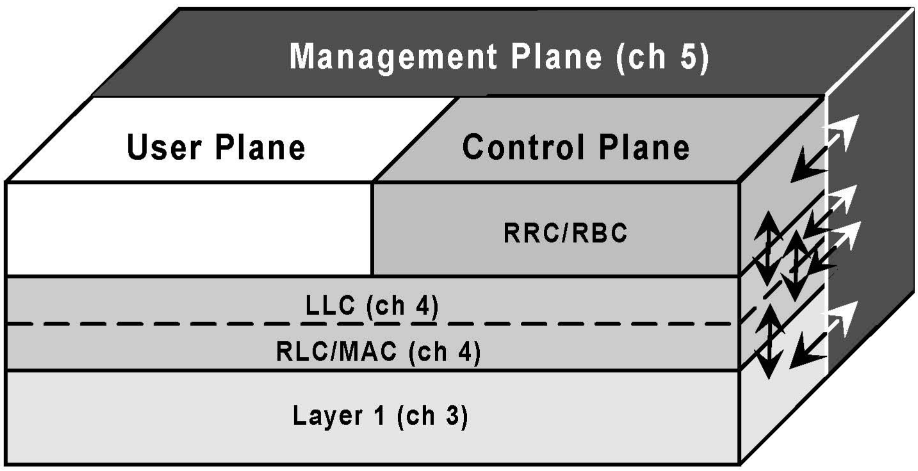



Figure 1-1 *The Layered Structure of WB-TDMA Radio Interface*

The radio interface comprises layered structure with Management, Control and User planes in the GRAN MT and in the GRAN BSS. The management plane extends as a uniform set of functionalities over all the layers and over the control and user planes. The functional entities in the management plane can handle both the inter-layer actions between any of the layers (not only the adjacent layers) and actions targeted to the control and the user planes.

The physical layer (L1) has no division between the control and the user planes.

*Table 1-1 Layer 1 of the Evaluated WB-TDMA scheme*

| **Main MA parameters** | **WB-TDMA** |
|---|---|
| Multiple access method | TDMA |
| Duplexing method | FDD and TDD |
| Channel spacing | 1.6 MHz |
| Carrier bit rate | 2.6 Mbit/s / 5.2 Mbit/s |
| **Physical layer structure** | |
| Time slot structure | 16 or 64 slots/TDMA frame<br>Flexible frame structure |
| Frame length | 4.615 ms |
| Multirate concept | Multislot, flexible bursts |
| FEC codes | Rate Compatible Punctured Convolutional codes, Turbo Codes |
| ARQ scheme | Type II hybrid ARQ |
| Interleaving | Inter-slot and intra-slot interleaving |
| Modulation | Adaptive B-OQAM / Q-OQAM |
| Pulse shaping | Root Raised Cosine, roll-off = 0.35 |
| Detection | Coherent, based on midamble |
| Additional diversity means | Frequency hopping per frame or slot, Time hopping, Antenna diversity |
| **Other RTT features** | |
| Power control | Slow power control, 50 dB dynamic range |
| Handover | Mobile assisted hard handover<br>Soft handover possible |
| IF handover | Mobile assisted hard handover<br>Soft handover possible |
| Interference reduction | Joint detection optional |
| Channel allocation | Slow and fast DCA supported |

The radio link layer (L2) has two sublayers, the LLC sublayer and the RLC/MAC sublayer. The control plane and the user plane are not separated in the LLC sublayer as it offers common Service Access Points (SAP) to access its transport mechanisms. The LLC provides the only service access points of the radio interface for the higher layers. The LLC is intended for both layer 3 signalling and for data transport. The transport mechanisms are provided in either HDLC-mode or minimum mode. The HDLC-mode has error detection, error correction , flow control and segmentation capabilities, whereas minimum mode has only the smallest subset of these.

The RLC/MAC sublayer will offer compact message structures to enable efficient and flexible communication between the peer-to-peer entities over the air interface. The RLC-messages can carry either control or user data messages or both of them in a specified way. The MAC will transport control messages between its peer-to-peer entities. MAC operates in the control plane, as it controls the RLC task to transport Service Data Units (SDU) of the higher layers. State machines for L2 will mostly be the same for the control and the user planes.

The radio network layer (L3) operates in the control plane. It comprises of Radio Bearer Control and Radio Resource Control sublayers. The RNL uses a Service Access Point of the LLC-sublayer to transport its messages between the peer-to-peer entities over the air interface. The RBC protocol has different entities for each radio bearer and it handles procedures for the set-up, negotiation and release of the radio bearers. The RRC protocol handles procedures, which are not directly related to a single bearer, but control the common parameters by e.g. system information, paging, measurement reports, signalling for the algorithms and handover functionality.

User data in this document refers to any data from the user plane of layer 3 or any data from the higher layers. These messages will originate and terminate in the Core Network or in the Mobile Terminal.

# 2. Logical channels

The purpose of this chapter is to describe the logical channels required for data transfer on UMTS WB-TDMA radio interface. All logical channels are unidirectional.

## *2.1 Control Channels*

Control channels are intended to carry L3 and MAC signalling data.

### 2.1.1 Dedicated Control Channels

Dedicated Control Channels (DCCH) are point-to-point control channels that carry connection oriented messages.

1. Fast Associated Control Channel (FACCH) is a point-to-point channel in the uplink or downlink direction. The allocation of a FACCH is linked to the allocation of a TCH. FACCH is used for the RLC/MAC layer messages, e.g. capacity allocations or link control messages.
2. Stand-alone DCCH (SDCCH) is a point-to-point channel in the uplink or downlink direction. The allocation of a SDCCH is not linked to the allocation of a TCH. SDCCH is used for the RLC/MAC layer messages.

### 2.1.2 Common Control Channels

Common Control Channels (CCCH) are point-to-multipoint control channels that carry connectionless or connection oriented messages.

1. Broadcast Control Channel (BCCH) is a point-to-multipoint control channel in the downlink direction. A BCCH is intended to broadcast a L3 and MAC signalling data.
2. Paging Channel (PCH) is a point-to-multipoint control channel in the downlink direction. A PCH is intended to broadcast L3 paging messages. The BS-MAC is responsible for ordering transmission on PCH according to L3 paging group information and retransmission requirements.
3. Random Access Channel for short access bursts (S-RACH) is a shared uplink channel and it is used for the messages transmitted in an access burst, e.g. Access Request message.
4. Random Access Channel for normal bursts (N-RACH) is a shared uplink channel and it is used for the messages transmitted in a normal burst, e.g. Capacity Request message and messages related to link adaptation.
5. Forward Access Channel (FACH) is a point-to-multipoint channel in the downlink direction. A FACH is used for transmitting MAC messages to MSs.
6. Uplink Acknowledgement Channel (UACH) is a point-to-point uplink channel which is used by the MSs to acknowledge the reception of message received in the FACH.
7. Forward Order Channel (FOCH) is a point-to-point channel in the uplink direction. A FOCH is used for NRT unit transmission requests for downlink NRT data transfer.
8. NRT Control Channel for downlink traffic (DNCCH) is a point-to-multipoint channel in the downlink direction. A DNCCH is used for broadcasting physical channel allocations and FO scheduling for downlink NRT data transfer. MSs with downlink reservation ID (RID) are expected to listen to DNCCH.
9. NRT Control Channel for uplink traffic (UNCCH) is a point-to-multipoint channel in the downlink direction. A UNCCH is used for broadcasting physical channel allocations and data unit transmission requests for uplink NRT data transfer. MSs with uplink reservation ID (RID) are expected to listen to UNCCH.
10. Public Power Control Channel (PWCCH) is a point-to-multipoint channel in the downlink direction. A PWCCH is used for broadcasting fast power control commands for each allocated timeslot.
11. Frequency Correction Channel (FCCH) is a point-to-multipoint downlink channel that is used by the mobile station to correct its frequency standard to coincide with the frequency standard of the BS.

12. Synchronisation channel (SCH) is a point-to-multipoint downlink channel that is used by the mobile station to synchronise with the TDMA multiframe structure of the BS.

## *2.2 Traffic Channels*

A Traffic Channel (TCH) is used for L3 signalling data and user data transfer.

## *2.3 Usage of the Dedicated and Common Control Channels*

For those messages which can be transmitted on CCCH (N-RACH in uplink, FACH in downlink, UACH always for acknowledging messages transmitted on FACH) or DCCH (SDCCH which allocated capacity or FACCH which uses capacity stolen from TCH) logical channel is selected by MAC. Guidelines for selecting the logical channel are following:

- If there is one or few MAC messages waiting for transmission, FACCH and CCCH are preferred to SDCCH.
- If the MS has allocation for a bearer and if the bearer parameters are such that stealing will not cause significant decrease to QoS, transmission on FACCH is preferred to CCCH.
- SDCCH capacity is allocated when several MAC messages need to be transmitted e.g. during the handover.

## *2.4 Mapping of Logical Channels to Physical Channels*

The purpose of this chapter is to describe the physical resource requirements for the logical channels specified in the previous chapter. Mapping of the control messages onto spread channels is ffs.

### 2.4.1 Control Channels

#### *2.4.1.1 Dedicated Control Channels*

1. Fast Associated Control Channel (FACCH) is mapped to TCH by stealing capacity allocated for a bearer service. FACCH can be mapped on any TCH allocated for the same MAC-identifier to which the MAC message is addressed to.

   Multiplexing and demultiplexing of FACCH on/from the traffic channels is done on burst by burst basis by altering between normal and FACCH training sequence. Stolen capacity causes predefined transmission format change to the burst by introducing a puncturing pattern to the transmitted data.
2. Stand-alone Dedicated Control Channel (SDCCH) is mapped to the physical channels according to channel allocation messages.

#### *2.4.1.2 Common Control Channels*

1. Broadcast Control Channel (BCCH)
2. Paging Channel (PCH) is interleaved over two to four 1/64 timeslots.
3. Random Access Channel for short access bursts (S-RACH) mapping is derived from cell broadcast. S-RACH is mapped to 1/64 (microcells) or 1/16 (macrocells) timeslots. 1/64 timeslot S-RACH allocation is not mandatory in a cell, in the microcells S-RACH can be mapped to the same physical channel with N-RACH.
4. Random Access Channel for normal bursts (N-RACH) capacity can be dynamically changed and it is derived from cell broadcast. If S-RACH is mapped to the same physical channel with N-RACH, both normal and access bursts are expected. Additional N-RACHs can be dynamically allocated and Control Capacity Allocation can used to indicate selected MSs the new location of N-RACH. N-RACH is mapped to 1/64 timeslots.
5. Forward Access Channel (FACH) capacity can be dynamically changed and it follows a predefined rule derived from cell broadcast. Additional FACHs can be dynamically allocated and Control

Capacity Allocation can used to indicate selected MSs the new location of FACH. FACH is mapped to 1/64 timeslots.

6. Uplink Acknowledgement Channel (UACH) allocation is linked to the allocation of FACH. UACH is also mapped to 1/64 timeslots.
7. Several Forward Order Channels (FOCH) may share the same physical resource. FO is interleaved into two 1/64 timeslots over two subsequent TDMA-frames. The FOCH scheduling is broadcast on the DNCCH.
8. Each NRT Control Channel for downlink traffic (DNCCH) message is mapped over two 1/64 timeslots in subsequent TDMA-frames.
9. Each NRT Control Channel for uplink traffic (UNCCH) message is mapped over two 1/64 timeslots in subsequent TDMA-frames.
10. PWCCH
11. Frequency Correction Channel (FCCH). The frequency correction burst is sent in one 1/64 slot.
12. Synchronisation Channel (SCH). The synchronisation burst can be sent in one 1/64 slot or in one 1/16 slot.

### 2.4.2 Traffic Channels

A Traffic Channel (TCH) is mapped to the physical channels according to channel allocation messages.

### 2.4.3 Channel Combinations

At a given moment, a MS accesses only a limited number of the logical channels. One of the following combinations is always accessed:

1. BCCH
2. BCCH + PCH + S-RACH + AGCH
3. BCCH + FACH + UACH + S/N-RACH
4. S/N-RACH + FACH + UACH

Combination 1. is normally used only in the phase when the physical connection is not set.

Combination 2. is used when a MS has no established bearers and is actively listening to the paging messages.

Combination 3. is used after initial access procedure when a MS has established initial bearer.

Combinations 1.- 3. can be accessed on the first RF carrier.

Combination 4. can be used if MS is informed about broadcast information changes via dedicated control channels. If this channel combination should be used, MS is informed about the control channel location which can be on any RF carrier.

In addition to combination 3 and 4 any of the following combinations can be added:

5. SDCCH
6. TCH + FACCH
7. DNCCH + FOCH
8. UNCCH
9. TCH
10. PWCCH

Combinations 5. and 6. are used if a dedicated control channel is needed.

Combination 7. is used by an MS with downlink reservation ID. RF carrier of the DNCCH and downlink transmission is indicated in the NRT-CA message.

Combination 8. is used by an MS with uplink reservation ID. RF carrier of the UNCCH and uplink transmission is indicated in the NRT-CA message.

Combination 9. is used if a traffic channel is needed.

Combination 10. is listened by a MS on every RF carrier where MS has uplink transmission resource and hence MS having uplink allocations on several RF carriers has to listen to several PWCCHs.

## *2.5 Cell access and synchronisation (BCCH)*

When the power is switched on in a MS, it must be able to find the network and then to synchronise with it. During active call mobile must be able to monitor neighbouring cells and when needed to synchronise with them. In a wideband TDMA system, the introduction of GSM like beacon is seen to have a number of disadvantages:

- continuous beacon signal with fixed power causes unnecessary interference and thus decreases network capacity,

- beacon carrier can not have frequency hopping, which gives rise for an additional frequency planning.

Two potential solutions to overcome or diminish the problem indicated above are

1) Discontinuous wideband BCCH (1.6 MHz)

2) Continuous narrowband BCCH (200 kHz)

To enable the design of the single bandwidth terminal for *WB-TDMA* it might be desirable to select the first alternative. In the following, the discontinuous wideband BCCH is described in more detail.

### 2.5.1 Initial synchronisation

When the power is switched on, the mobile starts scanning frequencies. When it finds a 'strong' frequency, it begins to listen to it.

In every cell, there is one so called beacon frequency which includes BCCH timeslots. The BCCH multiframe structure follows a period of 51 frames. The multiframe includes five frequency synchronisation (FCCH) and five synchronisation (SCH) bursts as described in *Figure 2-1*. FCCH includes only constant sine-transmission and is used for frequency synchronisation. SCH includes a long training sequence for time synchronisation. SCH also includes base station identity code (BSIC) and frame number which gives the frame synchronisation.

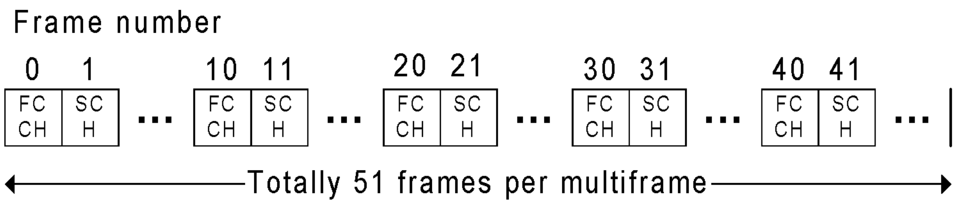



*Figure 2-1 GSM multiframe for BCCH-timeslot*

If a MS finds a FCCH burst it stays on that frequency, otherwise it must seek another strong frequency. The mobile receives several FCCHs and tunes its frequency oscillator. After that it is able to receive SCH and thus reach the time and frame synchronisation.

It would be beneficial if also the BCCH carrier could have frequency hopping. However, to make the initial synchronisation fast it is necessary that FCCH and SCH slots remain in a fixed frequency while the other slots of the BCCH carrier may hop. This requires an additional procedure called frequency hopping synchronisation here. A MS will learn the hopping pattern while listening to several SCH bursts that include information about the frequency hopping pattern. In the following, the overall initial synchronisation is summarised:

1. Find a strong frequency by power measurements
2. Frequency synchronisation (FCCH)

3. Time and frame synchronisation (SCH)
4. Frequency hopping synchronisation (several SCHs)

## 2.5.2 Neighbour monitoring

In GSM, the neighbour monitoring is based on the constant reference power transmitted on the beacon carrier. This carrier can not benefit from improvements like power control or DTX. In fact, if there is nothing to be transmitted in beacon carrier, then there must be transmitted bursts which do not contain any information (dummy-burst).

In WB-TDMA, constant power beacon carrier should be avoided due to the wider bandwidth and smaller number of carriers. However, accurate monitoring requires that the power to be measured is known. A solution is a non-continuous beacon signal which is transmitted short pre-determined time during each frame. To be able to make accurate measurements the mobile must know when this beacon signal is transmitted. Therefore, synchronous network is preferred although it is not required. Still, one has to be careful when transmitting the beacon signal in the pre-determined and fixed timeslot because some mobiles are not able to measure it. This can be avoided if beacon signal transmission would use time hopping according to the pre-determined pseudo-random sequence. These sequences should be different in neighbouring cells. Alternatively, the traffic channels of the MS can be rearranged to make these measurements available.

*Figure 2-2* shows an example about a beacon signal which is defined as a transmission of known power in beacon frequency. In each frame, one 1/16 time slot, selected according to the pre-determined pseudo random sequence, can be transmitted with the known power. This means that if there is not an active user in a slot, then dummy burst must be used. In the case of an active user, the transmission power in that particular slot is replaced by the power of beacon signal. In each frame, the beacon signal lasts pre-determined time (e.g. multiple of 72 μs). This value has to be set in such a way that all mobiles that may do handover to the cell can make measurements.

In each base station, there is a neighbour list, which contains all necessary information about beacon signal (frequency, transmitted signal power, the length of measurement window, pseudo-random sequence and the start of that sequence).

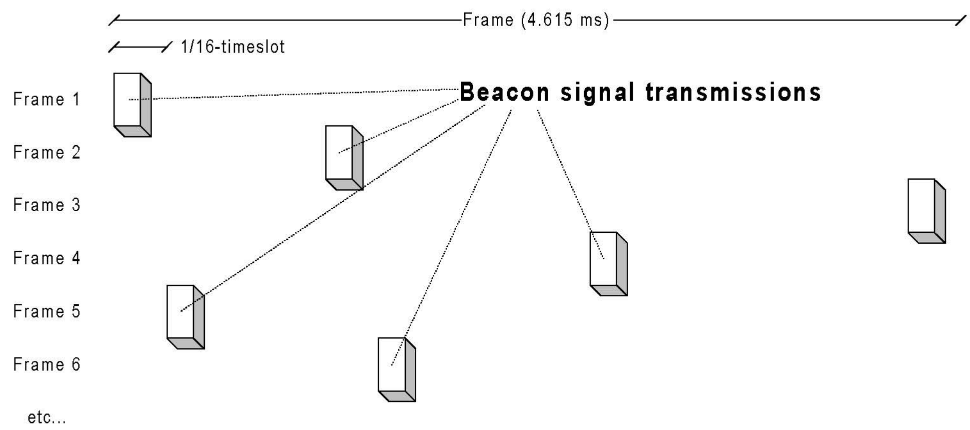



*Figure 2-2 An example about beacon signal.*

In cells, having only one transceiver and applying frequency hopping, the beacon signal is transmitted only when the beacon frequency is used (*Figure 2-3*). Because the beacon frequency is used relatively infrequently, the transmission of the beacon signal must last longer time to guarantee the possibility to measure it.

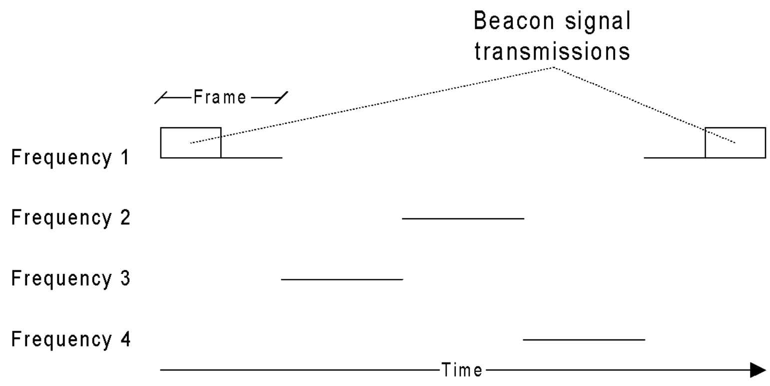



*Figure 2-3 Beacon signal transmission in frequency hopping BTS with one transceiver.*

### 2.5.3 Handover between WB-TDMA and GSM

Compatible multiframe structures of WB-TDMA and GSM make synchronisation of a MS to both systems feasible. This makes seamless handover for RT bearer services possible, and enables lossless handover for those NRT bearer services which can be established in both systems. It is preferable that WB-TDMA base station would maintain a neighbour list containing also the nearest GSM neighbours and vice versa. Then, a WB-TDMA mobile station could pre-synchronise with the strongest GSM neighbour cells and finally decide and execute the handover to GSM. The corresponding procedure can be applied to handover from GSM to WB-TDMA.

# 3. Physical channels

WB-TDMA can operate in FDD mode and in TDD mode. The channel spacing of WB-TDMA is 1.6 MHz both in FDD and in TDD mode. The basic physical channel of WB-TDMA is a certain time slot on a certain carrier frequency. In the following, an overview about the multiframe, unit frame and time slot structure is given. The last subsection defines the modulation method. The Wideband TDMA concept can be used in conjunction with other techniques. For example, a system with a TDMA downlink and CDMA uplink could be viable.

In order to efficiently cope with all radio environments and all services, a multi-band system concept is proposed and presented in section 3.2. A limited number of bandwidths are actually being considered in the evaluation, and the exact definition of these bandwidths might need to be reviewed at a later stage.

## *3.1 Multiframe*

The requirements for the multiframe structure come from two major directions. First, it is required that seamless handovers between WB-TDMA and GSM can be made. This implies a GSM like multiframe structure that can be further improved by taking into account the identified deficiencies in GSM. Secondly, the control requirements from the packet access protocol (RLC/MAC) have to be incorporated into the multiframe structure. One candidate multiframe structure is presented in *Figure 3-1*. The contents of the control channel cluster indicated in the figure is dependent on the higher layer protocols, too.

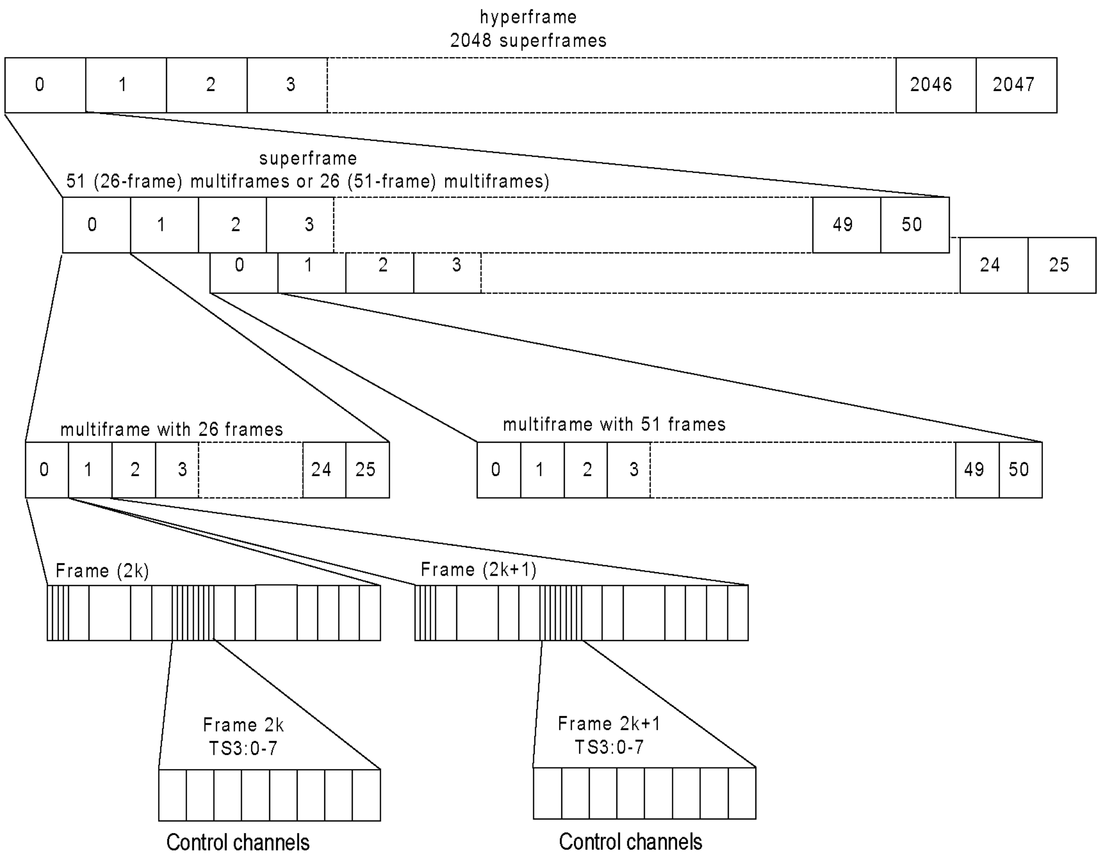



*Figure 3-1 A candidate multiframe structure that aims to provide compatibility with the GSM multiframe structure in order to make handovers between WB-TDMA and GSM possible.*

## *3.2 Multi-band concept*

### 3.2.1 Definition

With TDMA systems, it is difficult to handle efficiently all radio environments (delay spread) and the wide range of UMTS bit rates using a single carrier bandwidth. For instance the 1.6 MHz bandwidth may not be optimal for low bit rate services in large cells (with large delay spread). Therefore a multi-band system concept is introduced in order to solve this issue.

The TDMA multi-band system concept may use different bandwidths defined as :

$$BW = 2^n \times 100 \text{ kHz}, \text{ n from 1 to a maximum value M to be defined}$$

In order to be compatible with GSM, a basic carrier spacing of 200 kHz is chosen.

A TDMA multi-band system is illustrated on Figure 3-2 below, where the system can exploit 200, 400, 800, 1600 and 3200 kHz bands. However, in the current phase, only two carriers bandwidths are further studied, i.e. 200 kHz and 1600 kHz. The support of 3200 kHz could be considered in a later stage in order to support high bit rates with binary modulation, as well as the support of intermediate carrier bandwidths.

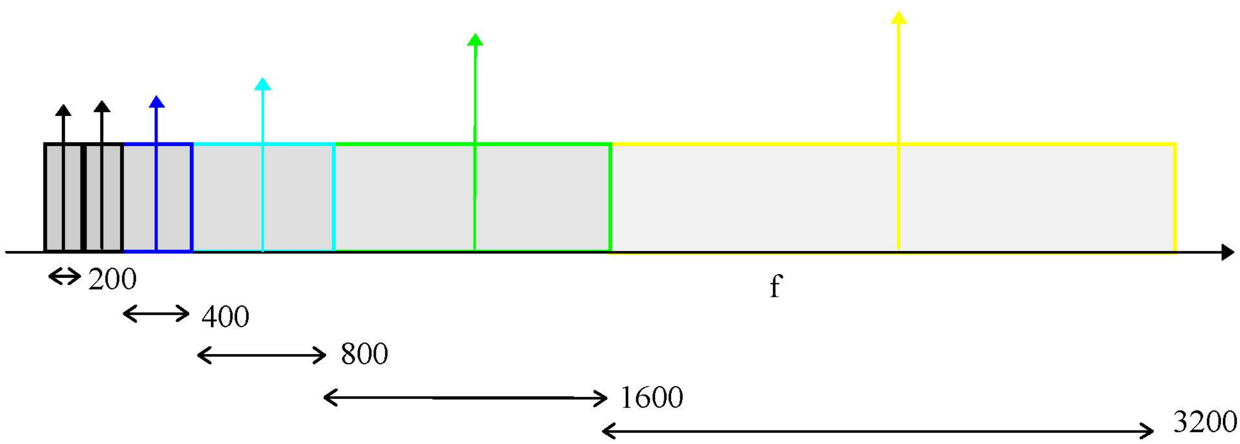



*Figure 3-2 :- Multi-band TDMA system concept*

It is pointed out that adjacent carriers might be used in the same cell, with different carrier bandwidths. A high adjacent channel protection will therefore be needed in order to avoid interference from adjacent channels, especially when different bandwidths are in use.

## *3.3 FDD and TDD frames*

In the following sections, a unit frame structure is presented separately for FDD and TDD modes.

### 3.3.1 FDD frame

The unit FDD frame is presented in *Figure 3-3*. The length of the FDD frame is 4.615 ms which is 12000 symbol periods.

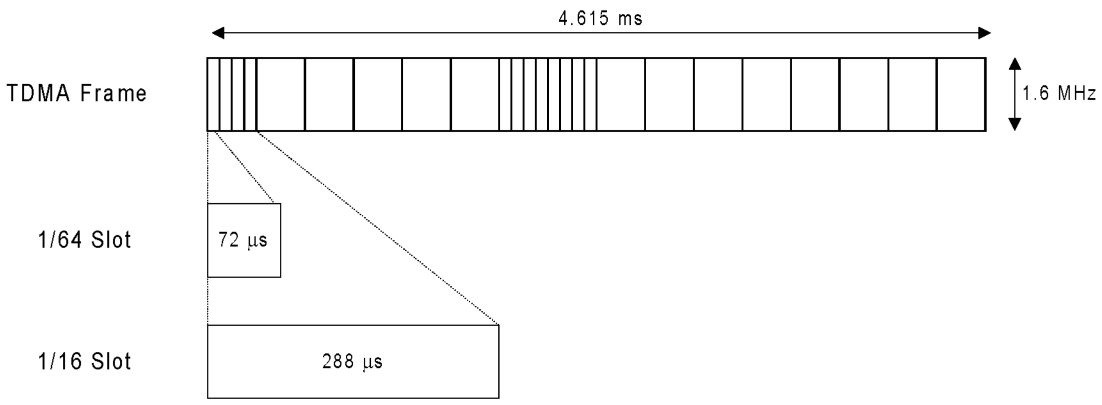



*Figure 3-3 The unit FDD frame structure of WB-TDMA. WB-TDMA without spreading uses 1/64 and 1/16 slots.*

### 3.3.2 TDD frame

The TDD frame is of the same length as the FDD frame but it is divided into downlink and uplink parts (*Figure 3-4*). The switching point between uplink and downlink can be moved in the TDD frame to adopt asymmetric traffic. The minimum length of uplink and downlink parts is one eighth of the frame length (577 µs).

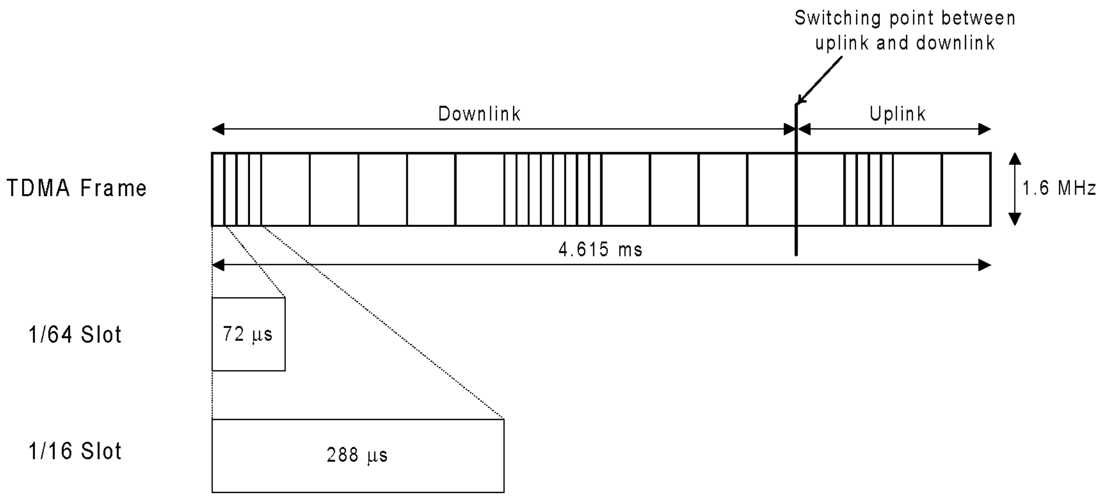



*Figure 3-4 The unit TDD frame structure of WB-TDMA..*

In the TDD frame structure, it is assumed that the same mobile station is not receiving in the last slot of the downlink part and transmitting in the first slot of the uplink part.

### 3.3.3 Time slots

The TDMA frame is subdivided into time slots. Two different types of time slots are presented for WB-TDMA in *Figure 3-3* and in Table 3-1 : 1/64 time slot and 1/16 time slot. In a 1/64 time slot there are 187.5 symbol periods and in a 1/16 time slot 750 symbol periods.

*Table 3-1 : Time slot lengths in seconds and in symbol periods.*

| Time slot type | Length in seconds | Length in symbol periods (SP) |
|---|---|---|
| 1/64 time slot | 72 µs | 187.5 SP |
| 1/16 time slot | 288 µs | 750 SP |

A TDMA frame of length 4.615 ms can consist of

- 64 1/64 time slots of length 72 µs (15/208 ms) or
- 16 1/16 time slots of length 288 µs (15/52 ms) or
- any mix of these time slots of different lengths fitting together in the TDMA frame.

The 1/64 slot can be used for every service from low rate speech and data to high rate data services. The 1/16 slot is to be used for medium to high rate data services.

The physical content of the time slots are the bursts of corresponding length as described in Section 3.4.

## *3.4 Bursts*

### 3.4.1 Traffic bursts for the 1.6 MHz carrier

Three types of traffic bursts are defined for WB-TDMA: the Speech burst 1 (S1), the Speech burst 2 (S2) and the Data burst (D). In addition, mulitplexed burst (MB) and flexible burst (FB) are introduced into the WB-TDMA concept.

#### *3.4.1.1 Data burst*

The Data burst uses 1/16 time slot. It consists of two tail symbol fields, two data symbol fields, training sequence field and guard period (*Figure 3-5*). The use of individual symbols is defined in *Table 3-2*.

The payload of the Data burst (number of data symbols) is 684 symbols. The training sequence is located in the middle of the burst so that none of the data symbols is too far from it. This improves the channel estimate compared to the use of the preamble type training sequence. Burst tail symbols are defined to have fixed value (e.g. 0's) in order to make different detection methods possible. In the end of the burst there is the guard period of 11 symbol periods. The guard period is a protection interval between bursts for time alignment uncertainty, time dispersion and power ramping.

Data burst can be used for all services from medium rate data (64 kbps) to high rate data up to 2 Mbit/s.

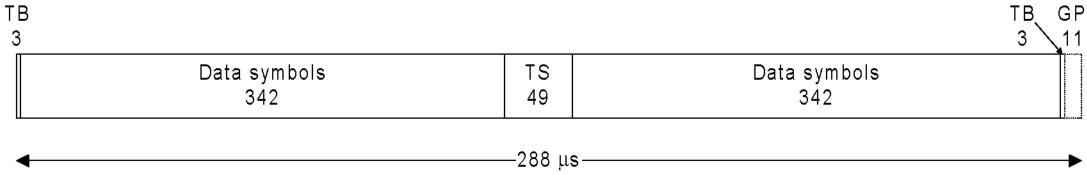



*Figure 3-5 Burst structure of the Data burst. TB stands for burst tail symbol, TS for training sequence and GP for guard period.*

*Table 3-2 : The contents of the Data burst fields and the use of individual symbols*

| Symbol number (SN) | Length of field | Contents of field |
|---|---|---|
| 0-2 | 3 | Tail symbols |
| 3-344 | 342 | Data symbols |
| 345-393 | 49 | Training sequence |
| 394-735 | 342 | Data symbols |
| 736-738 | 3 | Tail symbols |
| 739-749 | 11 | Guard period |

#### *3.4.1.2 Speech bursts 1 and 2*

The Speech bursts use 1/64 time slot. There are two types of Speech bursts that differ in the length of the training sequence. The training sequence of the Speech burst 1 is 49 symbol periods long whereas the training sequence of the Speech burst 2 is 27 symbol periods long. Thus the Speech burst 1 provides better channel estimate and allows for longer multipath delays than the Speech burst 2 by sacrificing some of the burst payload.

The Speech bursts 1 and 2 consist of two tail symbol fields, two data symbol fields, training sequence field and guard period (*Figure 3-6* and *Figure 3-7*). The payloads (number of data symbols) of the Speech bursts 1 and 2 are 122 symbols and 144 symbols, respectively. The use of the individual symbols is defined in *Table 3-3* and *Table 3-4*.

Both burst formats (Speech 1 and 2) can be used for all services from speech to high rate data up to 2 Mbit/s.

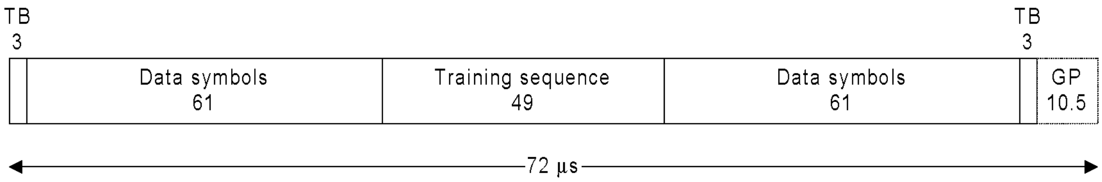



*Figure 3-6 Burst structure of the Speech burst 1. TB stands for burst tail bit and GP for guard period.*

*Table 3-3 : The contents of the Speech burst 1 fields and the use of individual symbols.*

| Symbol number (SN) | Length of field | Contents of field |
|---|---|---|
| 0-2 | 3 | Tail symbols |
| 3-63 | 61 | Data symbols |
| 64-112 | 49 | Training sequence |
| 113-173 | 61 | Data symbols |
| 174-176 | 3 | Tail symbols |
| 177-187 | 10.5 | Guard period |

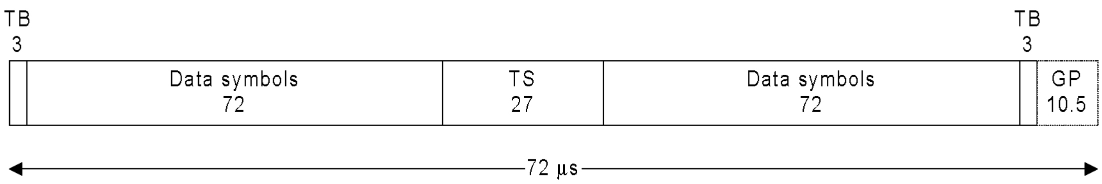



*Figure 3-7 Burst structure of the Speech burst 2. TB stands for burst tail bit, TS for training sequence and GP for guard period.*

*Table 3-4 : The contents of the Speech burst 2 fields and the use of individual symbols.*

| Symbol number (SN) | Length of field | Contents of field |
|---|---|---|
| 0-2 | 3 | Tail symbols |
| 3-74 | 72 | Data symbols |
| 75-101 | 27 | Training sequence |
| 102-173 | 72 | Data symbols |
| 174-176 | 3 | Tail symbols |
| 177-187 | 10.5 | Guard period |

### *3.4.1.3 Multiplexed Burst*

The Multiplexed Burst is defined to occupy an integer number of adjacent 1/16 time slots, and is intended for use on the downlink. It is divided into a header and a body (*Figure 3-8*). The header contains an indication of which users have data in the body, and on the location and format of this data. The header is comprised of one or more of defined bursts (e.g. Speech Burst 1) while the body contains any number of flexible bursts.

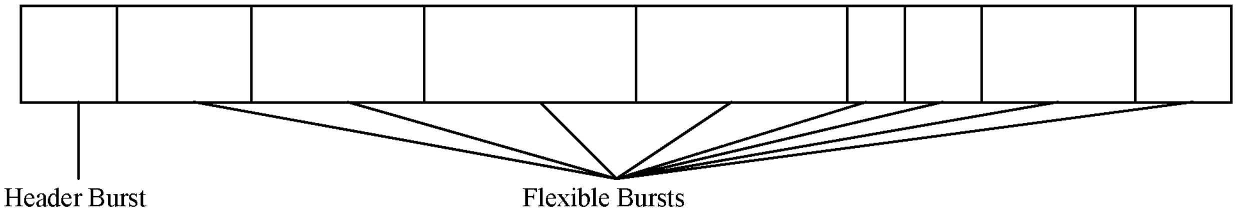



*Figure 3-8 Multiplexed burst*

The header may be reduced in size or eliminated, if sufficient information can be provided to the mobiles with reasonable efficiency using signalling defined for link adaptation mechanisms (cf., 5.3.3).

#### *3.4.1.4 Flexible Burst*

The allowed format(s) of flexible bursts (including modulation and coding scheme) are agreed between the mobile and base on call set up, or via a signalling channel. As an example (*Figure 3-9*) we consider a burst of a similar structure to the Data burst, but with a variable number of data symbols (ND) and variable length of training sequence (NT).

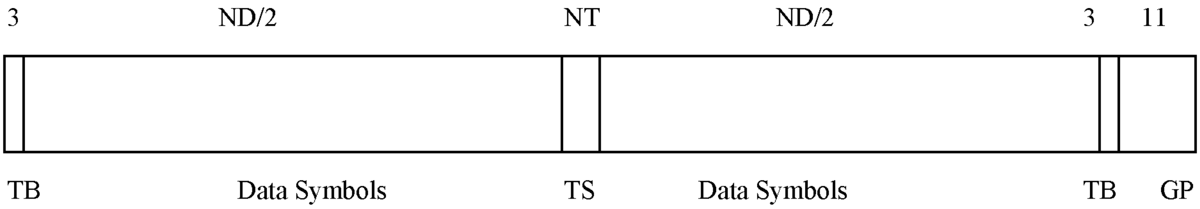



*Figure 3-9 Structure of Flexible Burst*

*Table 3-5* : Contents of Flexible Burst

| **Symbol Number** | **Length of field** | **Contents of field** |
|---|---|---|
| 0 - 2 | 3 | Tail symbols |
| 3 - (2+ND/2) | ND/2 | Data symbols |
| (3+ND/2) - (2+ND/2+TS) | NT | Training sequence |
| (3+ND/2+TS) - (2+ND+TS) | ND/2 | Data symbols |
| (3+ND+TS) - (5+ND+TS) | 3 | Tail symbols |
| (6+ND+TS) - (16+ND+TS) | 11 | Guard period |

Note that it may be possible to significantly reduce the guard period, which in the downlink would only be required to accommodate power ramping.“

### 3.4.2 Traffic bursts for the 200 kHz carrier

The 200 kHz is first being defined to support low bit rate services (speech) in large cells, but could be extended for the support of higher bit rates using quaternary modulation. Two types of bursts are defined for the 200 kHz carrier : the 1/8 burst and the 1/16 burst.

### *3.4.2.1 1/8 burst*

The 1/8 burst is very similar to the GSM, which eases compatibility with GSM. A smaller guard time is proposed, taking into consideration progress in technology of power amplifiers.

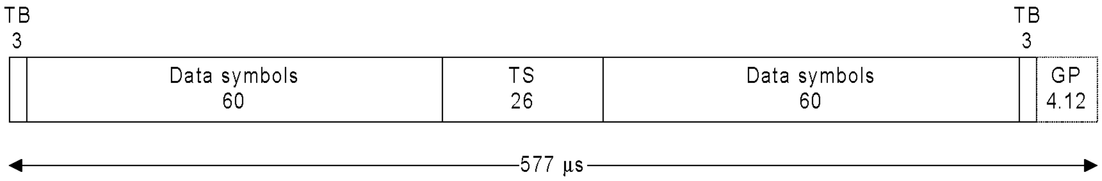



*Figure 3-10 : Burst structure of the 1/8 burst for 200 kHz carrier. TB stands for burst tail bit, TS for training sequence and GP for guard period.*

*Table 3-6 : The contents of the 1/8 burst for 200 kHz fields and the use of individual symbols.*

| Symbol number (SN) | Length of field | Contents of field |
|---|---|---|
| 0-2 | 3 | Tail symbols |
| 3-62 | 60 | Data symbols |
| 63-88 | 26 | Training sequence |
| 89-148 | 60 | Data symbols |
| 149-152 | 3 | Tail symbols |
| 153-157 | 4.12 | Guard period |

### *3.4.2.2 1/16 burst*

A 1/16 burst is proposed in order to improve the frequency diversity gain provided by frequency hopping. Indeed, for the same bit rate, instead of using a 1/8 slot, a mobile can use two 1/16 slots and hop inside the frame. The 1/16 slot also permits to offer lower bit rate services that could be useful for very low bit rate data or speech in some cases.

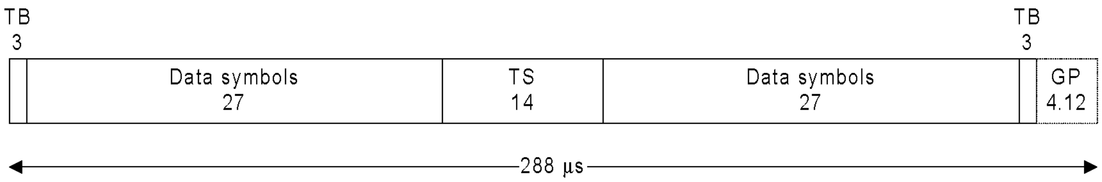



*Figure 3-11 : Burst structure of the 1/16 burst for 200 kHz carrier. TB stands for burst tail bit, TS for training sequence and GP for guard period.*

*Table 3-7 : The contents of the 1/16 burst for 200 kHz carrier fields and the use of individual symbols.*

| Symbol number (SN) | Length of field | Contents of field |
|---|---|---|
| 0-2 | 3 | Tail symbols |
| 3-29 | 27 | Data symbols |
| 30-43 | 14 | Training sequence |
| 44-70 | 27 | Data symbols |
| 71-73 | 3 | Tail symbols |
| 74-78 | 4.12 | Guard period |

The concept of multiplexed burst or flexible burst could be applied as well to the 200 kHz carrier, although details have not been developed yet.

### 3.4.3 Synchronisation bursts

Three different bursts are defined for synchronisation purposes: one frequency correction burst and two different synchronisation bursts. The actual synchronisation procedure is defined in Section 2.3.

#### *3.4.3.1 Frequency correction burst*

To enable the MS to synchronise to the BS carrier frequency the Frequency correction burst is used. This burst is used only in the downlink. The Frequency correction burst is sent using a 1/64-slot. It is for further study whether the longer burst (1/16-slot) for frequency correction is needed. *Figure 3-12* and *Table 3-8* show the 1/64-slot Frequency correction burst.

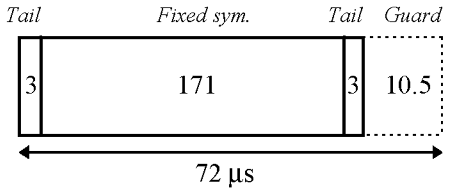



*Figure 3-12 The Frequency correction burst.*

*Table 3-8: The contents of the Frequency correction burst*

| Symbol number (SN) | Length of field | Contents of field |
|---|---|---|
| 0-2 | 3 | Tail symbols |
| 3-173 | 171 | Fixed symbols |
| 174-176 | 3 | Tail symbols |
| 177-186.5 | 10.5 | Guard symbols |

The fixed bits in the burst are all 0's. This gives that the transmitted signal is equivalent to an unmodulated carrier with an offset of approximately 651 kHz from the carrier frequency, which can be seen from the following equation ($\pi/2$-rotation for each symbol):

$$f_{offset} = \frac{1}{4 \cdot T_{sym}} \approx 651 kHz \qquad (3\text{-}1)$$

#### *3.4.3.2 Synchronisation burst*

To enable the MS to synchronise to the BTS TDMA structure, the Synchronisation burst is used. This burst is used only in the downlink. *Figure 3-13* and *Table 3-9* show the 1/16-slot Synchronisation burst and *Figure 3-14* and *Table 3-10* show the 1/64-slot Synchronisation burst. In the data fields these bursts carry information about the TDMA structure. These bursts have a significantly longer training sequence than the traffic bursts. The length of the data field for the 1/16-slot burst is probably unnecessary long, but on the other hand a longer training sequence would probably not be needed. The question is if the length of the training sequence field for the 1/64-slot burst is long enough and also if the data fields are long enough. If they are sufficiently long, probably only the 1/64-slot burst is needed.

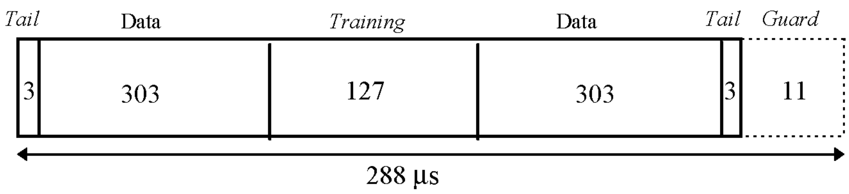



*Figure 3-13 The 1/16-slot Synchronisation burst.*

*Table 3-9 : The contents of the 1/16-slot Synchronisation burst.*

| Symbol number (SN) | Length of field | Contents of field |
|---|---|---|
| 0-2 | 3 | Tail symbols |
| 3-305 | 303 | Data symbols |
| 306-432 | 127 | Training sequence |
| 433-735 | 303 | Data symbols |
| 736-738 | 3 | Tail symbols |
| 739-749 | 11 | Guard period |

Training sequence for the 1/16-slot Synchronisation burst:

TS = ( 1 1 1 1 1 1 1 0 1 1 1 0 1 1 0 1 1 1 1 0 1 0 0 0 1 0 1 1 0 0 1 0 1 1 1 1 1 0 0 0 1 0 0 0 0 0 0 1 1
0 0 1 1 0 1 1 0 0 0 1 1 1 0 0 1 1 1 0 1 0 1 1 1 0 0 0 0 1 0 0 1 1 0 0 0 0 0 1 0 1 0 1 0 1 1 0 1 0
0 1 0 0 1 0 1 0 0 1 1 1 1 0 0 1 0 0 0 1 1 0 1 0 1 0 0 0 0 )

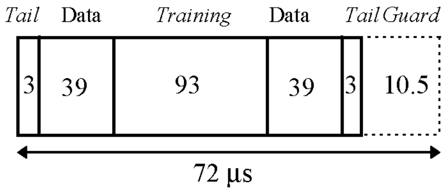



*Figure 3-14 The 1/64-slot Synchronisation burst*

*Table 3-10 : The contents of the 1/64-slot Synchronisation burst.*

| Symbol number (SN) | Length of field | Contents of field |
|---|---|---|
| 0-2 | 3 | Tail symbols |
| 3-41 | 39 | Data symbols |
| 42-134 | 93 | Training sequence |
| 135-173 | 39 | Data symbols |
| 174-176 | 3 | Tail symbols |
| 177-186.5 | 10.5 | Guard period |

Training sequence for the 1/64-slot Synchronisation burst:

TS = ( 0 0 1 0 1 0 0 1 0 1 1 1 1 1 0 1 0 1 0 1 0 0 0 0 1 0 1 1 0 1 1 1 0 0 1 1 1 0 0 1 0 1 0 1 1 0 0 1
1 0 0 0 0 0 1 1 0 1 1 0 1 0 1 1 1 0 1 0 0 0 1 1 0 0 1 0 0 0 1 0 0 0 0 0 0 0 1 0 0 1 0 0 1 )

The 1/64-burst Synchronisation burst consists of 25 information symbols, 10 parity symbols and 4 tail symbols. The 78 data symbols are obtained by a convolutional code of rate ½.

### 3.4.4 Access burst

The Access burst is used for initial random access and after/for handover. The modulation is BOQAM. Since timing advance is not known at initial random access and handover, a longer guard period is needed for the Access burst than for traffic bursts. The length of the guard period, $t_{guard}$, limits the maximum radius, $r_{max}$, of the cell, which can be seen in the equation below.

$$r_{\max} = \frac{c \cdot t_{guard}}{2} \qquad (3\text{-}2)$$

where $c$ is the speed of light.

In *Table 3-11* one can find the maximum cell radius for the two bursts. As can be seen, the 1/16-slot Access burst, the guard of which is set to 625 symbols, can handle cells with radius up to 36 km, while the 1/64-slot Access burst, the guard of which is set to 98.5 symbols, can handle cells with 5 km radius.

*Table 3-11 : Maximum cell radius for the two access bursts.*

| Slot type | Slot length [ms] | $t_{guard}$ [ms] | $r_{max}$ [ km] |
|---|---|---|---|
| 1/16 | 288 | 240 | 36 |
| 1/64 | 72 | 33 | 5 |

*Figure 3-15* and *Table 3-12* show the 1/16-slot Access burst and *Figure 3-16* and *Table 3-13* show the 1/64-slot Access burst.

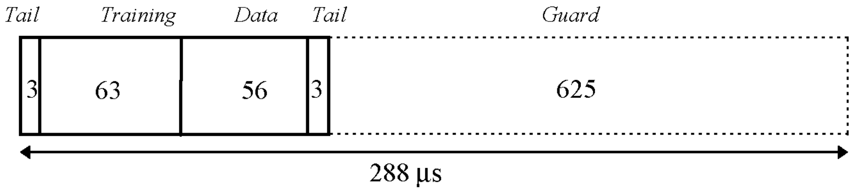



*Figure 3-15 The 1/16-slot Access burst.*

*Table 3-12 : The contents of the 1/16-slot Access burst.*

| Symbol number (SN) | Length of field | Contents of field |
|---|---|---|
| 0-2 | 3 | Tail symbols |
| 3-65 | 63 | Training sequence |
| 66-121 | 56 | Data symbols |
| 122-124 | 3 | Tail symbols |
| 125-749 | 625 | Guard symbols |

Training sequence for the 1/16-slot Access burst:

TS = ( 1 1 1 1 1 0 0 0 0 0 1 0 0 0 0 1 1 0 0 0 1 0 1 0 0 1 1 1 1 0 1 0 0 0 1 1 1 0 0 1 0 0 1 0 1 1 0 1 1
1 0 1 1 0 0 1 1 0 1 0 1 0 1 )

The 1/16-burst Access burst consists of 18 information symbols, 6 parity symbols and 4 tail symbols. The 56 data symbols are obtained by a convolutional code of rate ½.

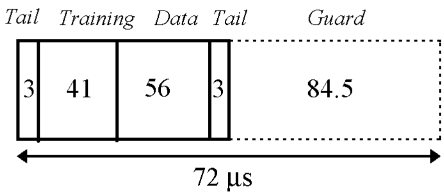



*Figure 3-16 The 1/64-slot Access burst.*

*Table 3-13 : The contents of the 1/64-slot Access burst*

| Symbol number (SN) | Length of field | Contents of field |
|---|---|---|
| 0-2 | 3 | Tail symbols |
| 9-43 | 41 | Training sequence |
| 44-99 | 56 | Data symbols |
| 100-102 | 3 | Tail symbols |
| 103-186.5 | 84.5 | Guard symbols |

The training sequence for the 1/64-slot Access burst is:

TS = ( 0 1 0 0 1 0 1 1 0 1 1 1 1 1 1 1 1 0 0 1 1 0 0 1 1 0 1 0 1 0 1 0 0 0 1 1 1 1 0 0 0 )

The 1/64-slot Access burst consists of 18 information symbols, 6 parity symbols and 4 tail symbols. The 56 data symbols are obtained by a convolutional code of rate ½.

### 3.4.5 Training Adaptation

It is desirable to be able to adapt the duration of the training sequence to transmission conditions. For example, longer training sequences may be needed for channels with large delay spreads, or for low C/I. This can be done within the definition of the Flexible Burst in Chapter 3.4.1.4. Also the Flexible Burst allows the frequency of training sequences can be altered to optimise the trade-off between training overhead and throughput, by allowing more frequent channel measurements for environments with fast moving terminals and less frequent measurements for slow moving mobiles.

The set of defined uplink and downlink transmission bursts could also be extended. To avoid additional overhead from longer training sequences, bursts intended for low bit rate bearers could be designed specifically for use in alternate frames (or even less frequently). As an example, a 1/32 slot burst could be used every other frame instead of a 1/64 slot every frame.

Training adaptation can be supported as part of link adaptation and also needs appropriate channel measurements, for example of channel quality and delay spread.

## *3.5 Modulation*

The basic modulation parameters including pulse shaping are summarised in Table 3-14.

*Table 3-14 : Basic modulation parameters*

| | |
|---|---|
| Carrier symbol rate | 2.6 MSymbol/s |
| Carrier spacing | 1.6 MHz |
| Data modulation | Binary Offset QAM<br>Quaternary Offset QAM |
| Pulse shaping | Root Raised Cosine<br>(roll-off 0.35) |

### 3.5.1 Data modulation

In this section, symbol rates and durations are defined, the mapping of bits onto signal point constellation is shown and the pulse shaping is defined.

#### *3.5.1.1 Symbol rate*

The symbol rate and symbol duration are shown in Table 3-15.

*Table 3-15 : Summary of symbol rates and durations*

| | Symbol rate | Symbol duration |
|---|---|---|
| WB-TDMA | 2.6 Msymbol/s | 0.384 µs |

#### *3.5.1.2 Mapping of bits onto signal point constellation*

In WB-TDMA the data modulation is either Binary Offset QAM (BOQAM), which is sometimes also referred to as Offset QPSK (OQPSK), or Quaternary Offset QAM (QOQAM), which is sometimes also referred to as Offset 16QAM.

Offset QAM may in general be expressed as:

$$s(t)=\left[\sum_k a_{2k}h(t-2kT)\right]\cos(\omega_c t)-\left[\sum_k a_{2k+1}h(t-(2k+1)T)\right]\sin(\omega_c t), \qquad (3\text{-}3)$$

where $\omega_c=2\pi f_c$, $f_c$ is the carrier frequency, 1/T is the symbol rate ($T=T_b$ for Binary Offset QAM and $T=2T_b$ for Quaternary Offset QAM), $a_k$ is the kth data symbol taking on values of ±1 for Binary Offset QAM and ±1 and ±3 for Quaternary Offset QAM and h(t) is the impulse response of the shaping filter. The difference between Offset QAM and conventional QAM is the delay of T (half a symbol period for QAM) in the quadrature branch. This time shift prevents zero-crossing signal transitions, as shown in *Figure 3-17* and *Figure 3-18*. This improves the Peak-to-Average Power Ratio, which makes Offset QAM more suitable for using with non-linear amplifiers.

The complex envelope of an Offset QAM signal is

$$\begin{aligned}u(t)&=\sum_k\left[a_{2k}h(t-2kT)+j\,a_{2k+1}h(t-(2k+1)T)\right]\\&=\sum_k j^{(k\bmod 2)}a_k h(t-kT)\end{aligned} \qquad (3\text{-}4)$$

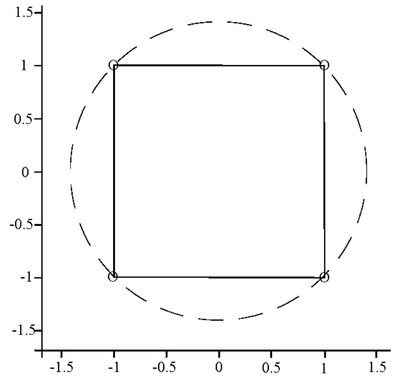



*Figure 3-17 Signal point constellation for BOQAM with rectangular pulse shaping (O, ——) and GMSK (----).*

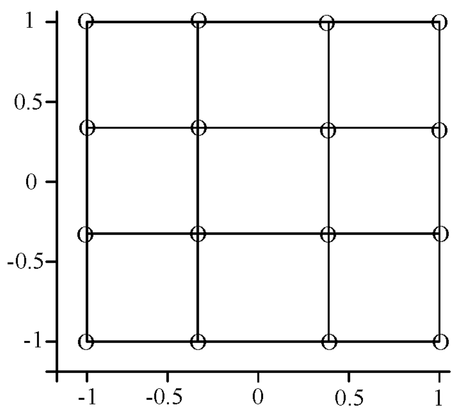



*Figure 3-18 Signal point constellation for QOQAM with rectangular pulse shaping (O, ——)*

### *3.5.1.3 Pulse shape filtering*

In WB-TDMA, the pulse shaping filter has square root raised cosine spectrum with impulse response given by:

$$h(t)=\sqrt{\frac{E}{2T}}\frac{1}{\pi t/2T}\left[\frac{\sin\pi(1-\alpha)t/2T+4\alpha t/2T\cos\pi(1+\alpha)t/2T}{1-(4\alpha t/2T)^2}\right], \qquad (3\text{-}3)$$

which is uniquely defined by the roll-off factor α. Here, the value 0.35 is chosen for the roll-off factor α. E is the energy of the pulse h(t) (usually normalised to 1). The impulse response h(t) and the energy density spectrum of h(t) with the roll-off factor α=0.35 are depicted in Figure 3-19.

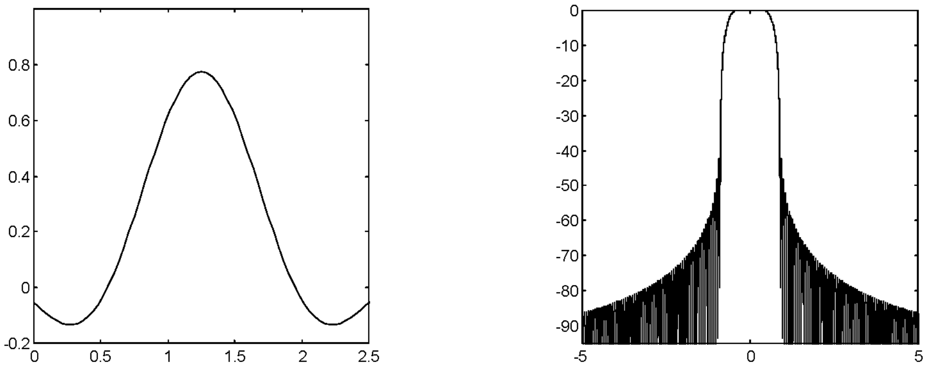



*Figure 3-19 Binary Offset QAM basic impulse h(t) and the corresponding energy density spectrum of h(t) with the roll-off factor $\alpha$=0.35 for a symbol duration 0.38 $\mu$s (1/2.6 Msymbol/s).*

### 3.5.2 Other modulation schemes

To allow maximum flexibility any modulation scheme supported by both base and mobile is allowed (including spreading). However, it must meet any relevant requirements on emission spectrum such as adjacent channel radiation. The modulations studied by FRAMES are a good basis for evaluating performance.

## *3.6 Examples of gross bit rates and service mappings*

This chapter presents the gross bit rates of WB-TDMA, some examples how the burst can be used to provide different data rates and how flexible bursts can be used in multirate services.

### 3.6.1 Gross bit rates of WB-TDMA bursts

*Table 3-16 : Gross bit rates of different burst types of WB-TDMA*

| Slot type | Burst type | Modulation | Gross bit rate per single slot (kbit/s) | Total gross bit rate (using all slots) (Mbit/s) |
|---|---|---|---|---|
| 1/64 | Speech 1 | BOQAM | 26.4 | 1.69 |
| 1/64 | Speech 1 | QOQAM | 52.8 | 3.38 |
| 1/64 | Speech 2 | BOQAM | 31.2 | 2.00 |
| 1/64 | Speech 2 | QOQAM | 62.4 | 4.00 |
| 1/16 | Data | BOQAM | 148.2 | 2.37 |
| 1/16 | Data | QOQAM | 296.4 | 4.74 |

### 3.6.2 Service mappings with WB-TDMA bursts

*Table 3-17 : Examples of service mappings for WB-TDMA*

| Required user bit rate (kbits/s) | Code rate | Slot type | Burst type | Modulation | Number of basic physical channels per frame |
|---|---|---|---|---|---|
| 8 | 0.5 | 1/64 | Speech 2 | BOQAM | 0.5 |
| 64 | 0.5 | 1/64 | Speech 2 | BOQAM | 4 |
| 144 | 0.5 | 1/16 | Data | BOQAM | 2 |
| 384 | 0.5 | 1/16 | Data | BOQAM | 5 |
| 1024 | 0.5 | 1/16 | Data | BOQAM | 14 |
| 2048 | 0.5 | 1/16 | Data | QOQAM | 14 |

### 3.6.3 Multirate concept with flexible bursts

The bit rate requirements for different applications could be met by using different modulation and coding schemes, as well as by allocation of a variable number of transmission slots. In the Adaptive Modulation concept the selection of the modulation and coding scheme is determined by the C/I at the mobile and the bit rate varied by adapting the slot duration.

As an example, the payload requirements for an 8kbps speech codec would vary from 40 symbols per frame (with Q-OQAM and 1/2 rate coding) to 120 symbols per frame (with B-OQAM and 1/3 rate coding). This assumes that 200 frames per second are used out of the available 216.68 frames per second (as in GSM). Therefore, using the Flexible Burst, and assuming training sequences of 27 symbols and 49 symbols respectively, the corresponding range of burst durations would be from 84 symbols to 186 symbols. The latter figure is almost the same as for the speech bursts.

Speech is considered to be a discontinuous data source, with a typical occupancy of 50%. Therefore efficient use of transmission capacity is achieved by multiplexing a number of such traffic channels into a Multiplexed Burst.

# 4. Layer 2 Radio Protocols

The following Figure 4-1 represents the layer structure and the protocols and algorithms of the WB-TDMA radio interface. Algorithms are represented in dashed boxes.

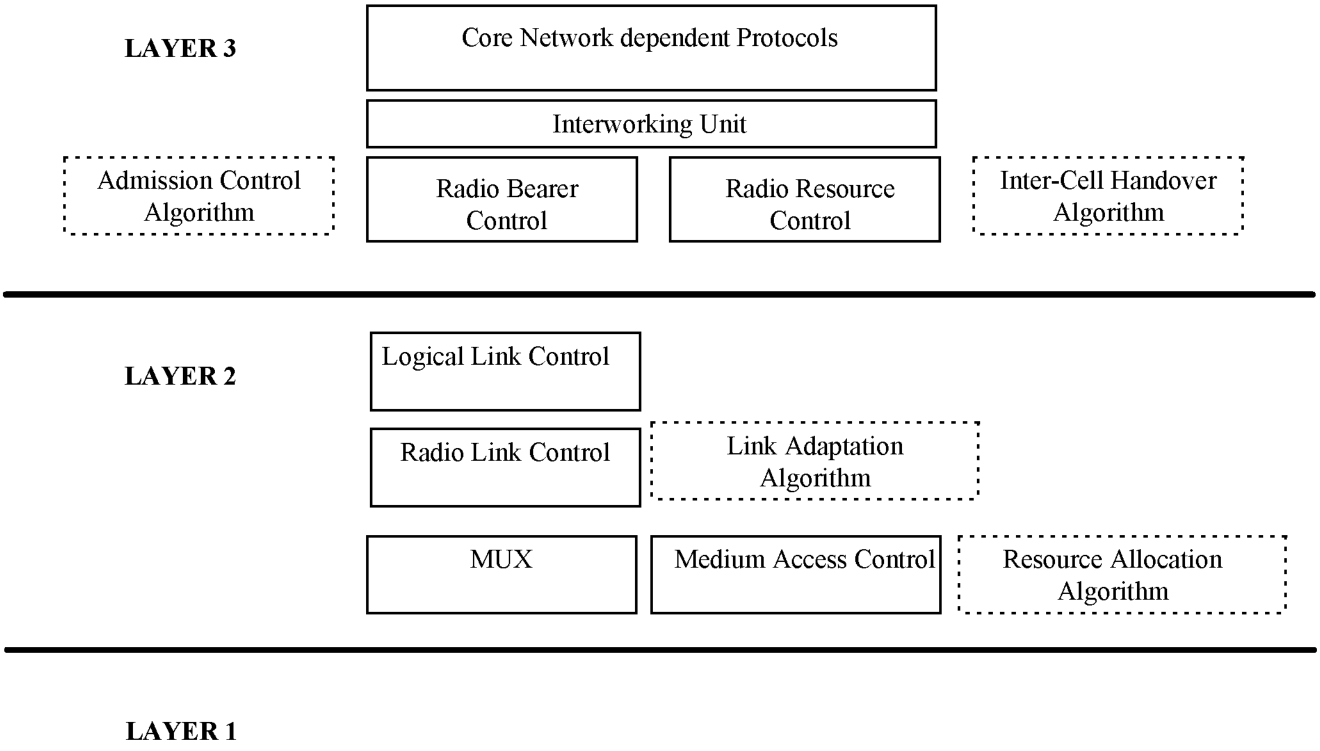



*Figure 4-1. WB-TDMA Radio interface*

## *4.1 Overview of layer 2*

The overall function of layer 2 is to realise radio bearers for layer 3 with respect to their QoS objectives. The first radio bearer, called the initial radio bearer, is mainly used to transport radio network layer (RNL) signalling, plus possibly messages destined to core network dependent control protocols. Other radio bearers are used to transport user data and network signalling. The initial radio bearer shall be maintained as long as other radio bearers have data to transfer. It is the last one to be released.

The set-up procedure for the initial radio bearer is triggered by layer 3 either after the reception of a paging message or because the MS wants to establish a connection to the fixed part of the core network. The set-up request is sent on a common uplink channel. The network allocates, in return, a MAC level identity to the MS. The procedure deals with collision and layer 3 solves contention between mobiles in order to guarantee that the MAC level identity is allocated to one and only one mobile. The MAC level identity is kept as long as the initial radio bearer is maintained. It is valid inside a given cell and has to be exchanged at each intercell handover.

The messages used to establish other radio bearers are layer 3 messages that are transported on the initial radio bearer.

Layer 2 is structured into two sub-layers (Figure 4-2) : the Logical Link Control (LLC) and the Radio Link Control / Medium Access Control (RLC/MAC) sub-layers. Service access points (SAP) are marked with dark dots. The RLC/MAC sub-layer has an internal structure. Therefore layer 2 is in fact composed of three types of protocol entities :

The LLC and RLC entities are created in association with a radio bearer and their function is to guarantee the negotiated QoS for the radio bearer.

The mobile MAC and network MAC entities are shared by all the radio bearers in one MS or one BS, respectively, and their main task is to dynamically split the radio resource between the bearers.

The reason why RLC and MAC are considered as belonging to the same sub-layer is that both entities have direct access to the physical layer and the LLC sub-layer.

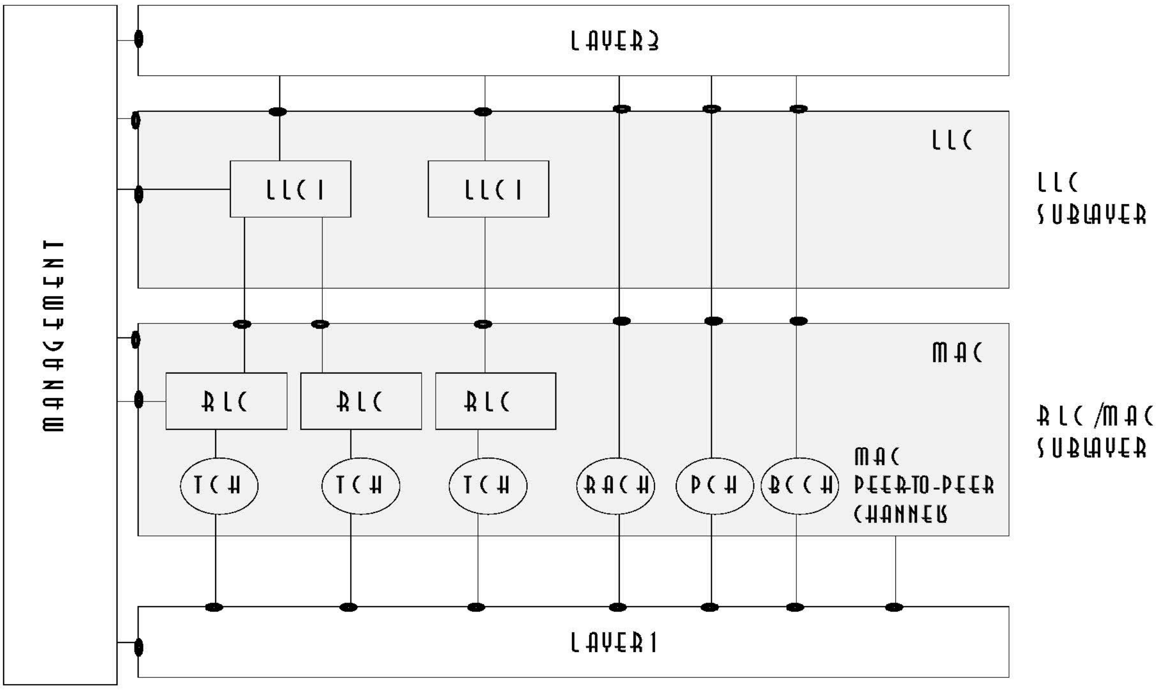



*Figure 4-2. Layer 2 internal structure*

The Layer 2 protocols are described in detail in the Gamma concept group document Tdoc SMG2 G19/97, Radio Protocols for WB-TDMA.

## *4.2 The LLC sub-layer*

The current working assumption is that the LLC protocol is located at the radio network controller (RNC) and in the MS.

The LLC sub-layer controls the data flow at layer 2 - layer 3 interface and transports it across the radio interface with error detection and correction levels appropriate to the QoS of the bearers. It expects from RLC/MAC a stable QoS level. Its control mechanisms are not designed to cater with radio fluctuations.

A pair of LLC entities (one in the MS and one in the network) is either associated to one single radio bearer or to a pair of radio bearers (one up-link and one down-link). The way the entities operate depends on the required QoS for the associated radio bearer or radio bearer couple. There are two operating modes :

HDLC mode. The transfer can be acknowledged or unacknowledged. In the acknowledged case, a backward signalling link is necessary to transport the acknowledgements and retransmission commands. This signalling link can either be dedicated or combined with layer 3 data. Independent data links with different priorities may be handled by peer LLC entities.

Minimum mode. The LLC sub-layer is completely transparent to the data. It mainly relays the data to the lower or to the upper layer.

## *4.3 The RLC/MAC sub-layer*

Although RLC/MAC has been defined as one layer which has one interface to the physical layer and one interface to the LLC layer, functions of the RLC part and the MAC part can be separated.

### 4.3.1 RLC

#### *4.3.1.1 Functions of RLC*

Two RLC entities (one in the MS and one in the network) are created by the management plane at each establishment of a radio bearer. These entities handle the service data units (SDU) coming from the LLC entities associated with the bearer. Their operating parameters are selected as a function of the QoS to be provided. A first task of RLC entities is to segment the SDU coming from LLC. A second task is to meet the QoS objectives that were assigned to them. For this purpose, they have elaborate control mechanisms at their disposal in order to deal with radio link quality fluctuations.

#### *4.3.1.2 RLC Protocol*

RLC entities are located both in mobile stations and in the network. The current working assumption is that the network RLCs are located in the base station. It has two operating modes, the first one to cater for real time (RT) transmissions and the second one to cater for non real time (NRT) transmissions. The RT mode uses power control and link adaptation mechanisms. The NRT mode uses power control and retransmission procedures (link adaptation for NRT services is realised with type-II hybrid ARQ, i.e. retransmission).

In the RT mode, the source RLC entity :

- Uses for the bearer a set of transmission formats (channel coding, interleaving, modulation) agreed at bearer set-up by layer 3.
- Has a dynamic set of traffic channels (TCH). This set can be reduced or increased through a request of the link adaptation algorithm to the local MAC entity (residing on the same side of the radio interface). Request may be done because e.g. there are traffic variations.
- Is in charge of splitting the LLC flow between the set of traffic channels (TCH). The transmission format is selected separately for each TCH. RLC segments the LLC data into RLC-protocol data units (PDU) in accordance with the chosen transmission format, optionally computes a CRC, and then delivers the PDU to the physical layer for transmission.
- In the RT mode, the sink RLC entity :
- Has a dynamic set of traffic channels (TCH) (the same as the one of the source RLC). This set can be reduced or increased through a request of the link adaptation algorithm to the local MAC entity. Request may be done because e.g. there are radio condition variations.
- Checks the CRC, if there is one, and discards the PDU if it is corrupted. Depending on the type of radio bearer the RLC entity is associated to, a corrupted PDU is either discarded or passed to LLC with a bad CRC indication.
- Assembles received PDUs and delivers the resulting SDU to LLC.

In the NRT mode, the source RLC :

- Uses the transmission format agreed at bearer set-up by layer 3.
- Indicates to local MAC the data amount which is to be transmitted. The peer RLCs deduce from the data amount and the agreed transmission format the adapted segmentation.
- Delivers PDUs to layer 1 when authorised by MAC, i.e. when resources are allocated to the radio bearer by the network.
- In the NRT mode, the sink RLC :
- Checks the CRC and alerts MAC when a PDU is received corrupted. It shall be noted that the role of RLC in the retransmission procedure is very limited. It only checks the CRC. All the signalling is handled by MAC entities.
- Assembles the correct PDUs and delivers SDU to LLC.

## 4.3.2 MAC

MAC entities are located both in mobile stations and in the network. They are respectively referred to as MS-MAC and BS-MAC (although it can be located in the RNC as well) in the following.

There is permanently one and only one MS-MAC entity per mobile. This entity is a state machine with two main states, the idle state when the mobile station is idle and the MS-MAC-Operation state once the mobile has established an initial radio bearer. In the idle state, the MS-MAC has received network and cell information broadcast on the BCCH. This information is used to make cell selection and points to the other common control channels used by MAC (PCH, RACH and FACH). MS-MAC listens to PCH where paging messages are received.

After a successful initial access procedure, MS-MAC enters the MS-MAC-Operation state. In this state, MS-MAC manages timing advance, power control and radio resources for the mobile station.

Timing advance management is used to align a mobile's transmission timing so that it closely matches the slot boundaries of the serving base station, compensating for transmission path delay. Transmission power levels are controlled in both directions. The control is made for each radio bearer with an option to adjust the power levels for each physical channel separately.

Radio resource management consists of allocating, exchanging and releasing physical channels to the radio bearer:

For RT radio bearers, the allocation mechanism is of circuit switched type, i.e. the physical channel allocation is valid up to the execution of a release procedure.

For NRT radio bearers, the allocation mechanism is of packet switched type, i.e. the allocation is only valid during an allocation period. This mechanism allows quick adaptation to load conditions because resources are not allocated for an indeterminate period of time. Furthermore, the MAC entities handle retransmission signalling when an RLC-PDU is received with a corrupted CRC.

There is permanently one BS-MAC entity per cell in the network. It broadcast information on the BCCH for the mobile stations which are in the idle state. It transmits paging messages on the PCH. It finally manages timing advance, power control and resources of all the radio bearers in the cell.

Peer MAC entities co-operate through the exchange of MAC messages. These messages do not encapsulate SDU from upper layers. Data primitives coming from or destined to upper layers are moved directly between layer 1 and the corresponding RLC. A CRC (Cyclic Redundancy Code) field is always part of a MAC message to enable the destination entity to check message validity. Messages and procedures used for radio resource management are detailed in 4.3.2.1 and 4.3.2.1.2. Messages and procedures used for NRT retransmission are presented in 4.3.2.1.2.1 to 4.3.2.1.2.2.

### *4.3.2.1 Signalling procedures for data transfer*

#### 4.3.2.1.1 RT operating mode

The important characteristic of the RT operating mode is that it allocates physical channels for an indeterminate period of time. A release procedure is necessary to liberate the resource. Several radio bearers cannot be multiplexed on one TCH. MAC uses an addressing scheme that allows the TCH to have a very precise granularity so that multiplexing is not necessary (one TCH is mapped onto one physical channel. This mapping can be in each TDMA frame, every second TDMA frame, every fourth TDMA frame, ..., up to every 128th TDMA frame).

##### *4.3.2.1.1.1 Network initiated procedures*

The network initiated procedures respond to radio condition variations for uplink radio bearers and bit rate variations for downlink radio bearers.

There are three types of commands : the allocation of a physical channel, the exchange of a physical channel for another one, the de-allocation of a physical channel. Whenever, for example, a network RLC asks the network MAC entity for more resources, the network MAC alerts the peer MAC with an "RT Capacity Allocation" message (*Figure 4-3*). This message indicates the concerned radio bearer and the physical channel allocated. It is acknowledged by an "RT Capacity Allocation Acknowledgement" message. The "RT Capacity Change" and "RT Capacity Deallocation" messages and their associated acknowledgements are used to exchange and liberate physical channels.

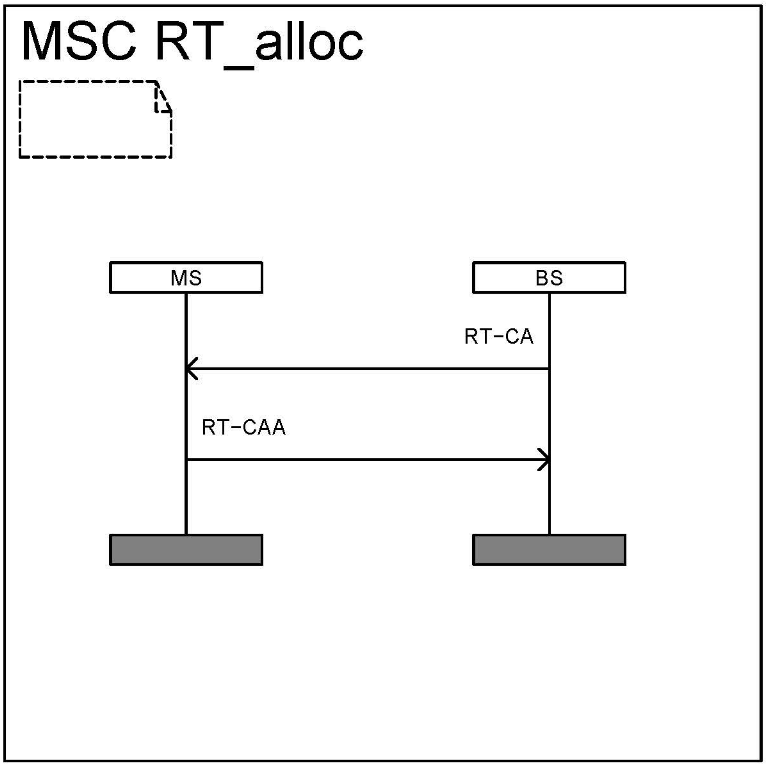



*Figure 4-3. Network initiated RT allocation*

#### *4.3.2.1.1.2 Mobile initiated procedures*

The mobile initiated procedures are due to radio condition variations for downlink radio bearers and bit rate variations for uplink radio bearers.

Whenever a mobile RLC requests a resource change from its MAC entity, it interprets the request into an "RT Capacity Request" MAC message (*Figure 4-4*). This message indicates the concerned radio bearer and the amount of resources needed. The capacity allocation procedure is similar for a mobile initiated procedure as described in Network initiated procedures. However, the channel allocation is initiated by the RT-CR message and not by the network RLC request.

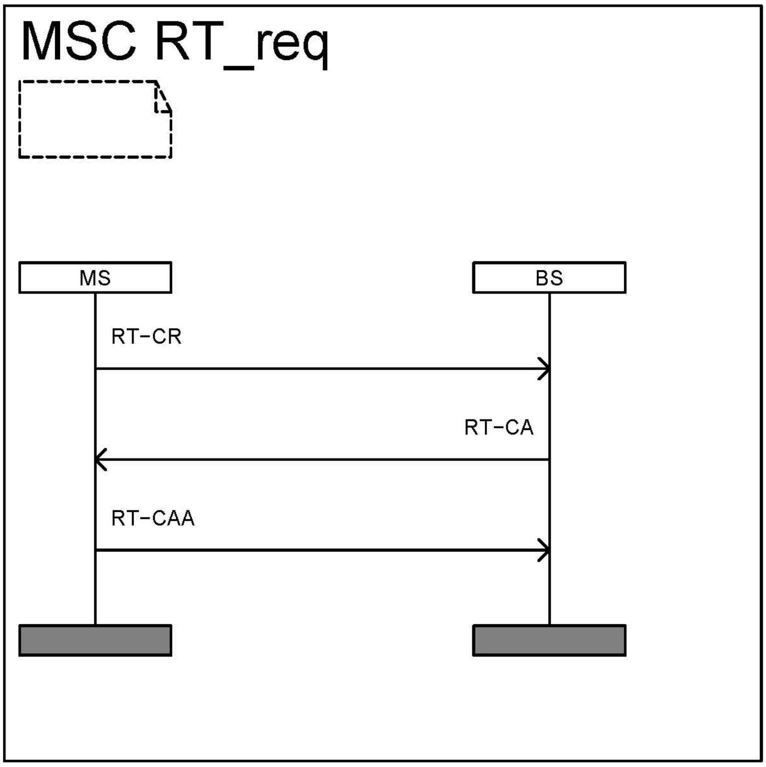



*Figure 4-4. Mobile initiated RT allocation*

#### 4.3.2.1.2 NRT operating mode

In NRT operating mode, resource allocation algorithm (in the network) knows the amount of data to transmit. Two NRT schemes are supported, the resource allocation algorithm being the one to decide which scheme is the more appropriate to the NRT radio bearer. In both schemes, the TCHs are allocated only allocation period by allocation period.

In the Scheduled Allocation NRT, only TCHs mapped on 1/16th physical channels are used and the allocation period is fixed to be two TDMA-frames. Two frames is considered to be a reasonable compromise between the flexibility of the NRT service (the acceptable load limit of a cell is affected by the ability of NRT-services to give way to RT-services, when required) and the control overhead and signalling error-rate involved. Two frames gives some interleaving gain, results in reasonable message size and is still very flexible. An NRT unit designates the two 1/16 bursts associated with a TCH during one allocation period. Because the network has to announce for each allocation period the TCHs splitting between the different NRT bearers, each active RLC is allocated a short identity (denoted RID) at the beginning of its source activity. This identity is valid until released by BS-MAC. In case of bad reception, the retransmission procedure allows a selective reject on a NRT unit per NRT unit.

In the second scheme, referred to as Immediate Allocation NRT, TCHs mapped on all types of physical channels (1/8th, 1/16th, 1/32th) can be allocated and the allocation period length is variable (2-32 TDMA frames). Allocations are announced for each TCH separately and associated  an allocation identity. In case of bad reception, the retransmission procedure allows an independent retransmission of the different allocations.

##### *4.3.2.1.2.1 Scheduled Allocation NRT procedures*

When the source of a downlink bearer activates, and BS-MAC decides to use scheduled allocation NRT capacity, the network MAC sends a “Scheduled Allocation NRT Capacity Allocation” message to the concerned mobile that indicates the bearer reference, and the RID (*Figure 4-5*). The message points as well to a pair of logical channels (downlink NRT control channel (DNCCH), forward order channel (FOCH)). The mobile acknowledges the SA NRT-CA with an “SA NRT Capacity Allocation Acknowledgement” message.

The mobile MAC entity is required to listen to the DNCCH. The splitting of physical channels between the RIDs is announced for each allocation period in a "Downlink NRT Control" message on the DNCCH (Figure 4-5). The mobiles indicate the list of NRT units that should be sent by BS in a "Forward Order" message. This message is sent on the FOCH, a common channel shared by several mobiles. The scheduling of FOCH usage is announced on the DNCCH.

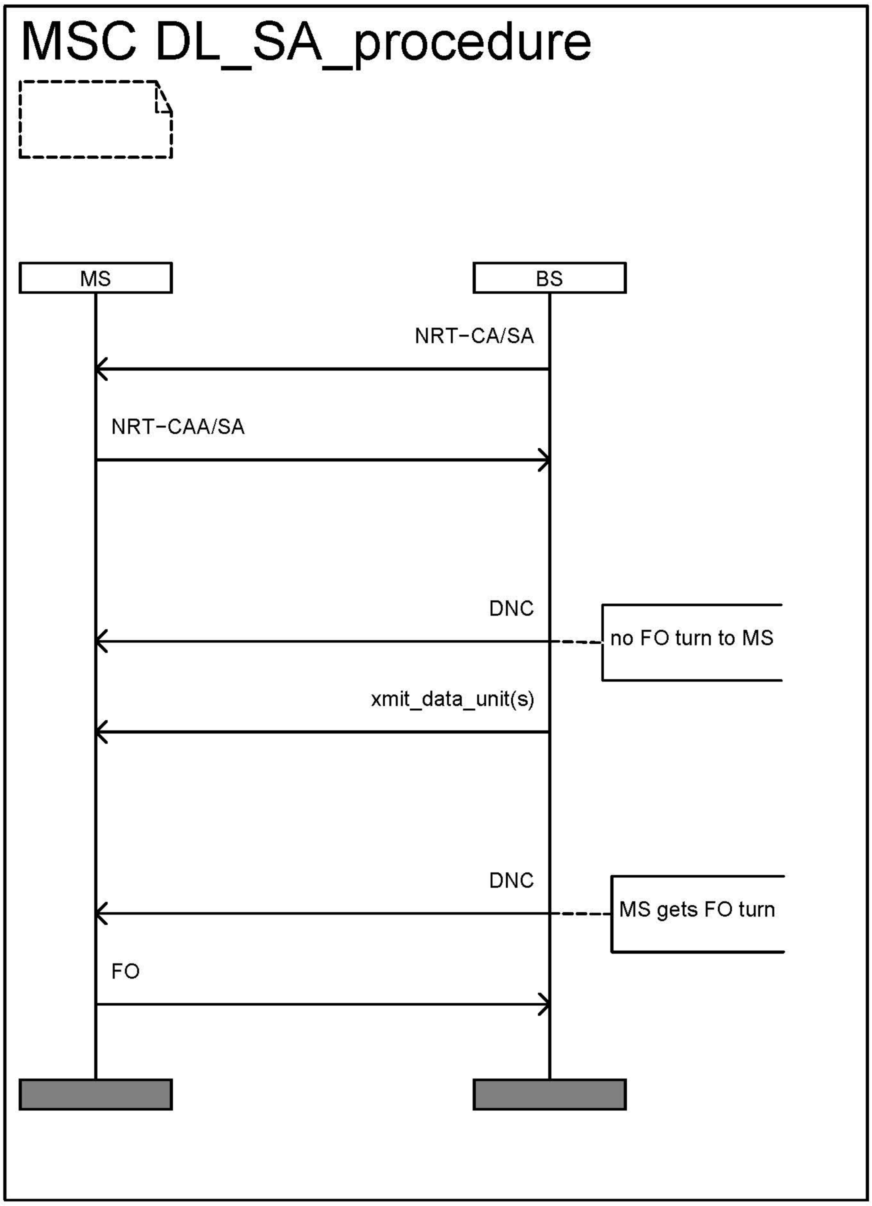



*Figure 4-5. Downlink Scheduled Allocation transmission*

When the source of an uplink bearer activates, the mobile MAC sends an "NRT Capacity Request" message to the network that indicates the bearer reference and the amount of data to transmit (*Figure 4-6*). If BS MAC decides to use scheduled allocation NRT capacity, it allocates in return an RID and announces the granted data amount in an "SA NRT Capacity Allocation" message. The message also points to an uplink NRT control channel (UNCCH) . Finally the mobile sends an acknowledgement with an "NRT Capacity Allocation Acknowledgement" message.

The splitting of physical channels between RIDs for each allocation period is announced by the BS-MAC in an "Uplink NRT Control" message on the UNCCH (*Figure 4-6*). The Uplink NRT control message also indicates the NRT units that should be sent in the allocated physical channels.

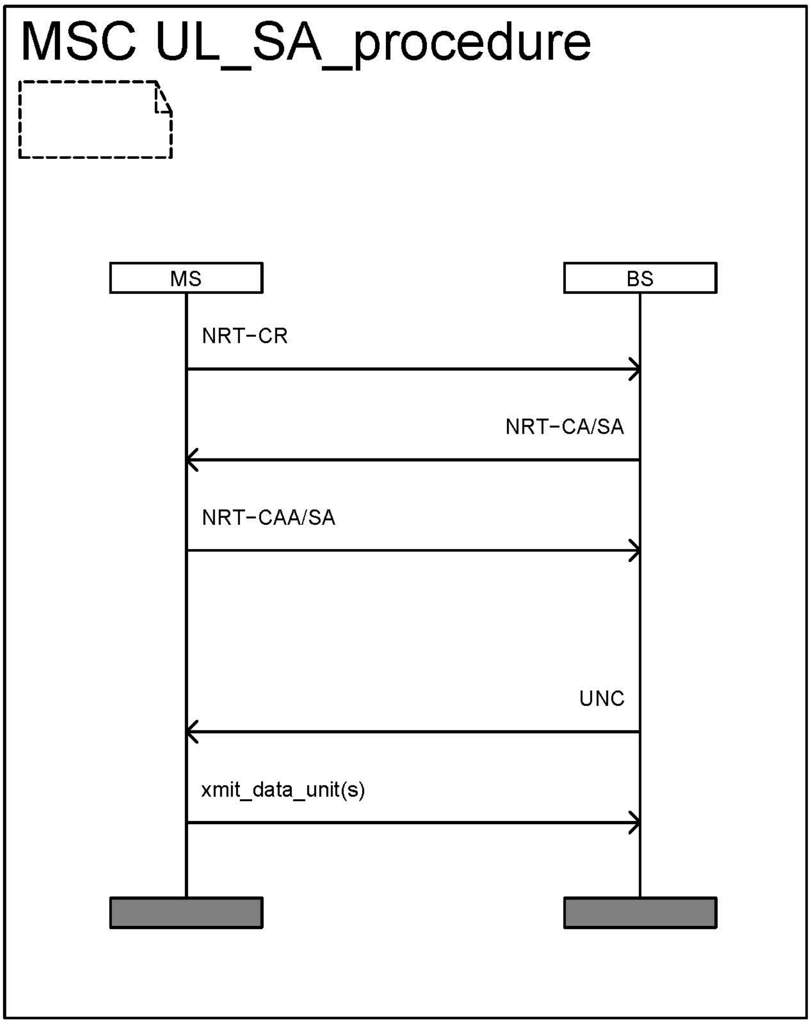



*Figure 4-6. Uplink Scheduled Allocation transmission*

The Scheduled Allocation NRT signalling allows the use of different retransmission schemes. Since, in any case, all NRT data is ordered by the receiver, the algorithms by which the orders are made are not required to be the same for all MSs. A more or less sophisticated retransmission scheme can be applied by the receiver. The most simple ARQ algorithm could be the normal type 1 ARQ where RLC-CRC is checked and according to the result the PDU is either accepted or discarded and requested to be retransmitted.

Good efficiency is however assumed to be achieved with following kind of type II hybrid ARQ scheme. An RLC-PDU is coded in a way that by transmitting a first part of it, it is already possible to decode the data. If the decoding is not successful then the rest of the coded data (containing redundancy to the first part) is transmitted. If the PDU decoding is not successful after having transmitted all of the data then some data units, preferably the ones with the lowest reception quality, are requested to be retransmitted until the decoding is successful.

### *4.3.2.1.2.2 Immediate Allocation NRT procedures*

Whether the Immediate Allocation is initiated by a BS-RLC request or after reception of an MS-MAC NRT Capacity request the procedure is almost the same. First BS-MAC sends an «Immediate Allocation NRT Capacity Allocation» message containing MAC-ID, Bearer-ID, Physical channel address, the length of the allocation period and an allocation identifier (*Figure 4-7* and *Figure 4-8*). Then the transmitting side transmits the NRT data accordingly. In the case of downlink transmission the MS MAC acknowledges the received data if the decoding of it was successful. In case of an uplink transmission, the BS MAC is informed by the local RLC whether the decoding was successful or not. For both transmission directions, if the decoding is not successful the BS-MAC sends an IA NRT-CA message with the same allocation identifier and the transmitter retransmits the data. This procedure is repeated until the decoding is found to be successful.

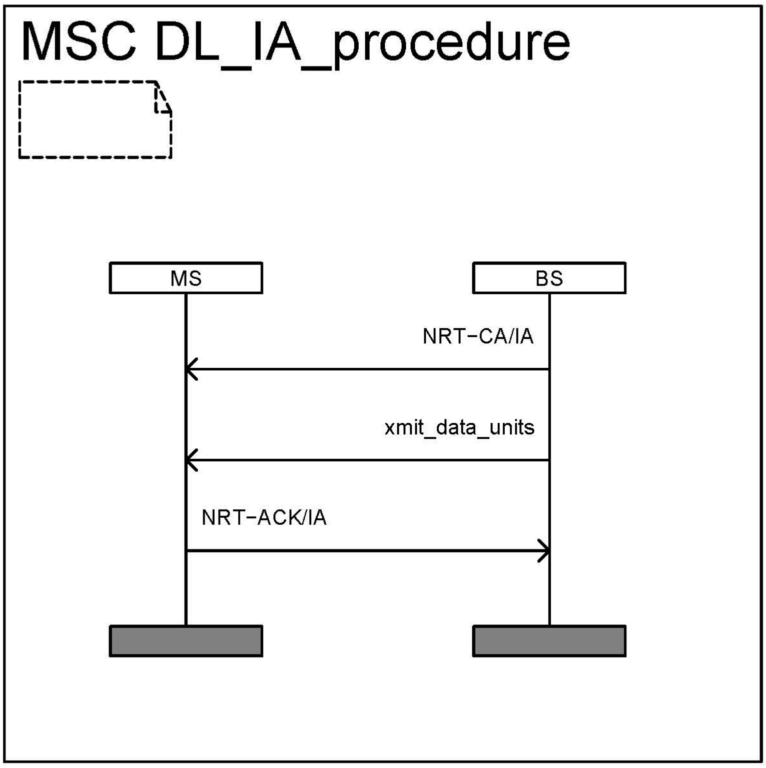



*Figure 4-7. Downlink Immediate Allocation transmission*

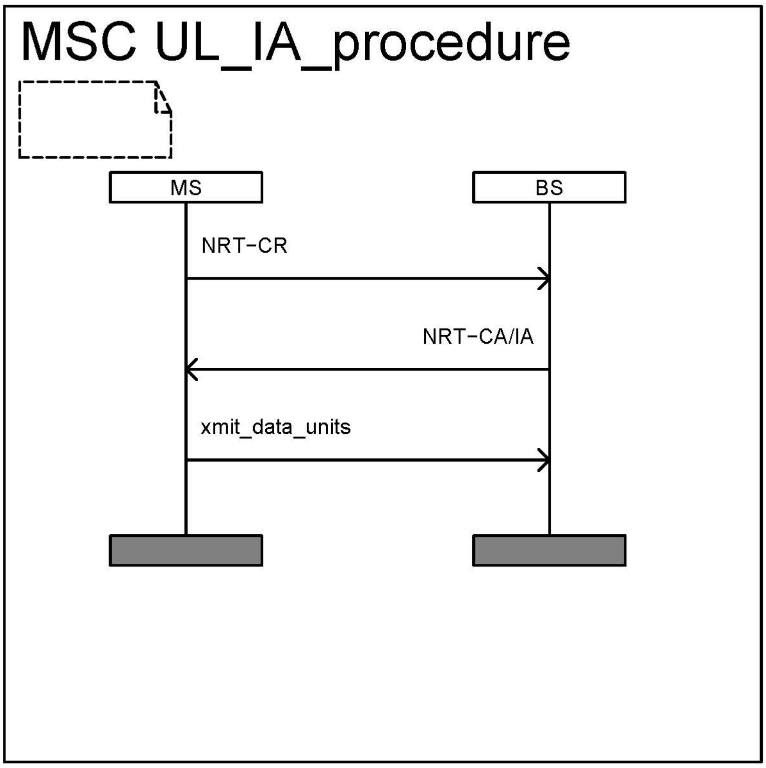



*Figure 4-8. Uplink Immediate Allocation transmission*

### *4.3.2.2 Signalling Procedures for Cell Management*

Note: In the following the MAC entity controlling the area of one cell (i.e. the area covered by one BS) is called BS-MAC. This MAC entity can be physically located in the RNC as well.

#### 4.3.2.2.1 Overview

RLC/MAC layer signalling procedures for cell management provide functions for control channel allocation and the transmission of cell system information.

#### 4.3.2.2.2 Control Channel Management

##### *4.3.2.2.2.1 Control Channel Capacity Allocation*

A CTRL-Capacity Allocation (CTRL-CA) message is used by the BS-MAC to allocate uplink or downlink SDCCH or to inform the MS about a new location of FACH (forward access channel) or N-RACH (random access channel for normal bursts).

The CTRL-Capacity Allocation Acknowledgement (CTRL-CAA) message is used by the MS to acknowledge the CTRL-Capacity Allocation.

If a CTRL-CAA is not received by the BS in a predefined time the status of the allocation must be solved by CTRL-CA or CTRL-Capacity Deallocation (CTRL-CD) signalling until the CTRL-CAA/CTRL-CDA has been received.

The procedure is similar as illustrated in Figure 4-3.

#### 4.3.2.2.3 System Information Broadcasts

L2 and L3 parameters to be transmitted on BCCH are ffs.

#### 4.3.2.2.4 Paging of the MSs

A paging message is transmitted by the network to page one or more MSs. The number of MSs that can be paged at a time depends on the way in which the mobiles are addressed.

#### 4.3.2.2.5 Handover Signalling

There are several handover procedures proposed for WB-TDMA. It is assumed that all bearers allocated to a mobile must be served by a single cell. Therefore, all bearers are handed over simultaneously. In addition to the normal signalling procedures layer 2 is expected to provide data flow suspension and resumption during the handover and handover access signalling to the new cell. Details of the WB-TDMA handover are ffs.

### *4.3.2.3 Signalling Procedures for Controlling the Radio Link*

MAC provides signalling procedures for timing advance, power control and measurement reporting.

#### 4.3.2.3.1 Timing Advance Adjustment

MS has to transmit something periodically to provide BS information needed to maintain the TA. If the MS has nothing to transmit then a specific Timing Advance Probe (TAP) message can be sent.

1In order to administer dynamic channel assignment on behalf of MS supporting multiple bearers, a BS-MAC must maintain a record of which physical channels are allocated for transmit and receive to each MS for all of its bearers. This record can be used as a basis for combining the time alignment measurements (made by layer 1) for all of a MS bearers to form a single estimate of time correction for the MS. Consequently, the BS-MAC (or a process associated with BS-MAC) will continuously monitor a MSs timing alignment based on measurements reported by layer 1.

If needed, the BS-MAC transmits a Timing Adjustment Correction (TAC) message which contains TA correction to be applied to all transmitted bursts. TAC message can be transmitted on common control channel (FACH) or dedicated control channel (SDCCH or FACCH). TAC message is not acknowledged by the MS-MAC.

The MS may stop the transmission of TA probes and then the MS will loose the time alignment. Such an MS willing again to start transmission to the BS has to send a TAP message in an access burst on S-RACH. As a response to the probe the BS will transmit TAC message.

It is ffs. whether BS could initiate transmission of the TAP by sending a polling message on FACH. A TAP message could be transmitted on UACH as a response to this polling message.

#### 4.3.2.3.2 Power Control

For slow power control the Power Control (PC) message can be transmitted on FACH, N-RACH or on any DCCH.

For the optional fast power control the use of FACCH, SDCCH and FACH is inappropriate for the transfer of power level reports. Instead, a Public power control channel PWCCH is adopted. This requires one 1/64 timeslot per frame and indicates the differential power setting to be applied. It has the advantage that it can support unidirectional bearers or bearers operating DTX but has the disadvantage that mobiles are required to be able to monitor a broadcast every frame.

The details of the power control can be found in document SMG2 Gamma 15/97.

#### 4.3.2.3.3 Measurement Reporting

The required signalling procedures depend on the RRM algorithms. It is possible that all measurements are transmitted over the radio interface in the L3 messages, and that the contents of the measurement report is distributed to the relevant algorithms by L3.

#### 4.3.2.3.4 Radio Link Failure

The time-out procedure for the radio link failure is for ffs.

#### 4.3.2.3.5 Adaptive Antennas

When adaptive antennas are used MS has to transmit something to provide BS information needed to estimate the location of the MS. If the MS has nothing to transmit then a specific probe (e.g. Timing Advance Probe message) can be sent.

Logical channels specified for RLC/MAC support use of adaptive antennas, except BCCH, PCH, DNCCH, UNCCH and PWCCH. These channels are broadcast simultaneously to several MSs. Logical channel are described in chapter 2.

The detailed requirements of adaptive antennas are for ffs.

# 5. Radio resource management

## *5.1 Introduction*

For WB-TDMA, FRAMES has chosen to study two RRM concepts : a decentralised solution with emphasis on interference diversity strategy, the so called *'interference averaging' concept,* and a centralised solution with the emphasis on interference minimisation strategy, the so called *'bunch' concept*. On a scale where each system is characterised by its grade of centralisation these two solutions take place on the two opposite ends of the scale. If both solutions can be supported in terms of the measurements and signalling provided in the system, it is likely that a wide variety of solutions situated on an intermediate position on this scale can be supported and deployed, responding to the requirements of future operators.. The Interference Averaging concept does not require central management of radio resources for interference minimisation reasons but is rather based on. frequency- and time-hopping to reach a common averaged interference level. On the contrary, the bunch concept assumes that a limited number of Remote Antenna Units are connected to a central unit. To reach a minimisation of intra-bunch interference the knowledge of all allocated resources, transmitter powers and path gains together with synchronisation between the cells is required. Inter-bunch interference is dealt with frequency and time hopping.

The Interference Averaging concept is proposed to be used in all kinds of environments and the bunch concept as an option for areas with high traffic. Both concepts are being further investigated. However, these concepts are just examples of a wide range of RRM schemes that can be supported with the signalling designed for these concepts.

In the following, a short description of the algorithms of the IA concept and an overview of the Bunch concept is given. The Radio Resource Management schemes are described in more detail in the Gamma Concept group document Tdoc SMG2 G15/97, Radio Resource Management for WB-TDMA.

## *5.2 Overview of the RRM scheme*

The main idea of the proposed set of Radio Resource Management (RRM) algorithms is to ensure the existence of a simple, robust and credible scheme for the FMA mode 1 without spreading. The cornerstone of the presented scheme is interference averaging. To achieve this frequency and time hopping (FH/TH) with a low re-use is proposed. Due to the interference averaging, all the used channels of a given cell in the system experience almost equal interference conditions. This simplifies greatly the RRM algorithms used. The intention is to prove by simulation that this scheme although suboptimal is very good. Also due the robustness of the proposed scheme it can in reality prove to be superior to many so-called 'optimal' schemes. The algorithms presented include Power Control (PC), Link Adaptation (LA), Quality Loop (QL), Automatic Repeat reQuest (ARQ), Admission Control (AC), Channel Allocation (CA) and Handover (HO).

The traffic to be handled can be divided into two classes, i.e. non-real-time (NRT) and real time (RT) traffic. For RT traffic a very simple Admission Control algorithm is applied. The Admission Control is based on a highest allowed fractional loading per cell (e.g. 25% to 70% of the allocated spectrum can be used for RT traffic in one cell). The value of the highest allowed fractional loading can be selected by the operator. The Power Control for RT traffic is C based (or RSSI based). C/I-based Power Control will be studied in the future. This is in conjunction with the higher allowed transmission power (as compared to NRT traffic) and the LA scheme ensures the quality of the RT traffic. The LA scheme for RT traffic is based on the adjustment of the gross bit rate of a bearer. The Handover for RT is based on a simple pathloss or C/I criteria.

For NRT traffic no Load Control beyond the natural hard limit provided by the number of channels is applied. This is due to the fact, that simulations have shown that for NRT traffic the best spectral efficiency is obtained with re-use 1 and a fractional load, i.e., a load of less than 100% full load. Power Control is C-based with a relatively low dynamic range. The ARQ process replaces both coding adaptation and fast C/I-based Power Control. This is due to the fact the ARQ algorithm is of type II (i.e. the ARQ algorithm increases the coding rate with the number of re-transmissions). The Handover for NRT traffic is based on the offered capacity from the candidate cells.

The proposed solutions may seem deceivingly simple at first, but preliminary simulations have shown that they are very effective. They are also extremely adaptive regarding to the JD/IC and adaptive antenna techniques. Also the robustness of the proposed scheme ensures that the operator can deploy capacity easily whenever and wherever needed.

## *5.3 Application of RRM techniques*

### 5.3.1 Time and Frequency Hopping

In the proposed system, time and frequency hopping techniques with hopping unit 1/16 slot are used. The characteristics of the MSs set the main constraints to the time and frequency hopping sequences. E.g. some of the WB-TDMA terminals may have only one receiver and they must have enough time between reception and transmission (as in GSM). In a system exploiting all hopping dimensions this kind of low end MSs can use only low bit rate services. In an isolated system, where hopping can be reduced, these MSs can use high bit rate services. The hopping sequences are for further study.

### 5.3.2 Power Control

The main purpose of Power Control is to adjust transmitter power levels in such a way that sufficient signal strengths are sustained at the receivers and power levels are minimised.

In the proposed system the Power Control algorithms are slightly different for the uplink and the downlink. C based Δ-modulation PC (i.e. PC commands are of the form step up or step down) is utilised in the uplink direction. The length of the control period can be e.g. 5-500 ms. For short control periods the step size is very small (for NRT traffic) and for long control periods it is larger (for RT traffic). The maximum allowed transmission powers may be different for RT and NRT services due to strict delay requirements of RT services. The initial power request is set based on the pathloss estimate to the serving BS. In the downlink direction the Power Control is also C based but it is slower. The length of the control period can be e.g. 100-500 ms.

Pathloss based PC has been selected for the first version of the proposed system, C/I-based Power Control is an item for further study.

### 5.3.3 Link Adaptation

The scope of LA is to dynamically adapt the transmission mode to the channel conditions so that the BER and delay requirements are met with a minimum system capacity (backward Link Adaptation). In addition to this, requests for more and less capacity are made based on the source rate changes (forward Link Adaptation). In the former case, the receiving end makes the request to BS and in the latter case the transmitting end makes the request to BS. The Link Adaptation functions by changing the number of slots allocated to the bearer.

At the bearer set-up a subset of all possible transmission modes is selected to be used. In this set-up procedure e.g. the MS's capability to use different codings and modulations is taken into account. The coding schemes can be expressed with rather coarse grid because puncturing is assumed to be used for the fine tuning. The transmission mode pool should be big enough to allow flexibility. It contains information about coding rate, coding type (e.g. convolutional, block, turbo, repetition), modulation (lower order or higher order modulation), interleaving depth/time, interleaving type (per channel / per bearer) and burst types.

For RT bearers the only channel coding and modulation will be adapted when a bearer exists. Interleaving and burst type are selected at the bearer set-up or during the HO. Interleaving is assumed to be performed over all slots of one RT bearer. For NRT bearers ARQ and modulation changes are used.

#### *5.3.3.1 Link Adaptation for RT services*

The Link Adaptation for RT is based on a quality function Q of the C/I of the received bursts over each interleaving period. The measurements of one bearer are averaged over all used frequencies and time slots. The LA algorithm decreases and increases the number of channels based on the quality Q and some threshold values. Link Adaptation is performed after each received interleaving period. LA signalling is not needed very often and it is preferably packet based.

In case of video service or other variable rate service, the adaptation to the source bit rate i.e. forward Link Adaptation, is necessary. Then the requested capacity is determined using the current coding and modulation. The possible extra space, due to the granularity of the slot size, is filled with additional coding (/ the lack of space is compensated with reduced coding) which is spread equally to all the slots of the bearer by puncturing or repetition. When a new channel is requested it takes some time before it is available if it can be allowed at all. This should be taken into account when making requests. The problem could be solved by requesting excess capacity.

#### *5.3.3.2 Link Adaptation for NRT services*

A combination of Automatic Repeat reQuests (ARQ) and Forward Error Correction (FEC), called as a hybrid-ARQ, can provide very low bit-error-rates. In this RRM scheme a type II hybrid-ARQ process, optimised especially for fading environment and WB-TDMA, is used as a main Link Adaptation technique for NRT bearers. Thus the network is insensitive to planning errors. Also the need for fast Power Control is removed by the ARQ scheme. The proposed ARQ scheme is expected to increase the capacity of the network. For more details about hybrid-ARQ, see chapter x.

In addition to ARQ, the modulation changes can be utilised in NRT services. A change to higher order modulation could be made then the function Q is over some threshold value and vice versa. The higher order modulation provides a higher bit rate but it is more sensitive to time dispersion, so this LA algorithm should be used only in small cell environments.

### 5.3.4 Quality Loop

The goal of the Quality Loop of the LA algorithm is to adjust the LA parameters to be such that the quality experienced by the bearer is sufficient. These parameters can either be set by the operator or they can be adaptive. In this version of the system the adaptive version is not covered. It will be a subject of future studies.

### 5.3.5 Slow Dynamic Channel Allocation

As described earlier each BS can use any frequency in the Interference Averaging concept. This also holds with the optional slow DCA scheme for a single HCS layer case presented here. Slow DCA has two phases called *slot prioritising* and *allocation of slots*.

> *Example: Consider an operator having 8 frequencies (8*1.6 MHz=12.8 MHz) to each direction. This equals to 512 1/64 slots to each direction. The frequency prioritising would prioritise the slots for each BS in the following manner. Each BS will get:*
>
> *1) 64 most preferred slots*
>
> *2) 64 second most preferred slots*
>
> *3) 128 third most preferred slots*
>
> *4) 256 fourth most preferred slots*

Prioritising over BSs is done so that if all the BSs used only their the most preferred slots, the network would have reuse pattern 8. If all BS used their most and second most preferred slots the network would have reuse pattern 4. If all BS used their most, second most and third most preferred slots, the network would have reuse pattern 2. Naturally if all BS used all their slots, the network would have reuse pattern 1.

The allocation of slots is done independently in each BS. Each BS checks the amount of requested resources and ‘activates’ the needed amount of slots.

> *Example (cont.): Each BS can activate either 64 , 128, 256 or 512 slots.*

All traffic slots will then hop randomly in time within the activated slots and the cyclic frequency hopping is used over the whole spectrum to get more channel diversity. Thus in case of effective reuse 1 this slow DCA will converge to default Interference Averaging concept with no frequency planning. If the slow DCA were done manually during the network set-up and network enhancements (frequency planning ), there would be no need for additional signalling nor measurements.

### 5.3.6 Fast Dynamic Channel Allocation

The scope of the (fast Dynamic) Channel Allocation algorithm is to keep the record of the channel usage and select channels for the new and existing bearers. The CA algorithm searches a feasible allocation based on priority and fragmentation criteria and the capabilities of the MSs. The priority list should take into account users i.e. relations between bearers. Fragmentation should be avoided because the shorter bursts cause more signalling and overhead. Also TDD option may set some constraints to the allocation. Apart from these conditions, the appointed or released channel is chosen from the set of free channels randomly, because of the averaging techniques used.

The channels are allocated to the RT bearers simply according to their priorities. The NRT services are treated as ‘best effort’. This means that the slots are first given to the RT bearers and the rest of the slots is available for NRT bearers. The slots are allocated to the NRT bearers according to their priorities. A NRT bearer has a high priority if it has a lot of data to transmit and vice versa. NRT bearers having difficulty of sustaining the agreed minimum bit rate are prioritised over other NRT bearers. The signalling load may become too heavy if very many NRT bearers are active at the same time so the number of simultaneous NRT bearers is limited.

### 5.3.7 Admission and Load Control

The purpose of Load Control is to maximise the achieved bit rate over the network by adjusting the number of slots of controllable rate bearers. In the proposed system no Load Control is applied. All the available slots are filled with data of NRT bearers. The Channel Allocation algorithm allocates the channels in a ‘fair’ manner.

The purpose of Admission Control is to ensure that the bearer requesting access into the system can be granted its QoS requirements without compromising the QoS requirements of the bearers already in the system. Admission Control is based on the amount of available slots in the given cell. The number of slots a bearer will use is estimated in both directions. In the uplink direction this estimation is simple, since the interference conditions are equal for all slots. In the downlink direction the estimation is done by the mobile. This Admission Control is performed in both directions of the incoming bearer.

For RT traffic a very simple Admission Control algorithm is applied. The Admission Control is based on a highest allowed fractional loading per cell (e.g. 25% to 70% of the allocated spectrum can be used for RT traffic in one cell). The value of the highest allowed fractional loading can be selected by the operator.

For NRT traffic no Load Control beyond the natural hard limit provided by the number of channels is applied. This is due to the fact, that simulations have shown that for NRT traffic the best spectral efficiency is obtained with re-use 1 and a fractional load, less than the 100% full load.

### 5.3.8 Inter-cell Handover initiation

The proposed Handover is a C/I based algorithm that requires frequency hopping and prefers also time hopping. This algorithm tries to select the BS that can provide best quality (C/I) to be the serving BS. Quality is estimated separately for each candidate BS before the actual Handover is initiated. For fast mobiles a macro cell connection is preferred.

All the BSs continuously calculate quantity which is a function of its own transmission power. The MSs measure pathlosses to candidate BSs and report them to the serving BS. This information is forwarded to the RNC (Radio Network Controller)where the Handover initiation decision is made. Also MS initiated HO is possible if the same information is signalled to the MS.

From this data, the average C/I an MS would experience in the new cell is estimated first. Then for each BS a loading factor that estimates the number of slots available for the MS is calculated. The loading factor is calculated separately for RT and NRT services and for both directions. The weighting factor combines the information about the expected C/I and the loading and it is calculated for each candidate BS. If the system load is asymmetric then the uplink and downlink can be weighted separately so that the more critical direction has higher influence on the decision. If the weighting factor of a BS is handover margin higher than the weighting factor of the serving BS, it is selected. If a user operates with a mixture of RT and NRT services the condition causes the MS to prefer the BS with high expected C/I, high number of available slots for NRT and a feasible number of slots for RT.

If the Handover is wanted to perform purely on pathloss basis then the RNC uses pathloss information provided by the MS instead of the above calculations for Handover decision.

### 5.3.9 Interactions between the RRM algorithms

Both the up- and downlink PC algorithms and the fast Dynamic Channel Allocation algorithm are located in the BS. The downlink PC may optionally locate in the MS. The up- and downlink LA and the Quality Loop (for further study) algorithms are located in the BS and MS respectively. The network initiated Handover, Admission Control and the slow DCA (for further study) are carried out in the RNC. The MS initiated HO is, naturally, performed in the MS.

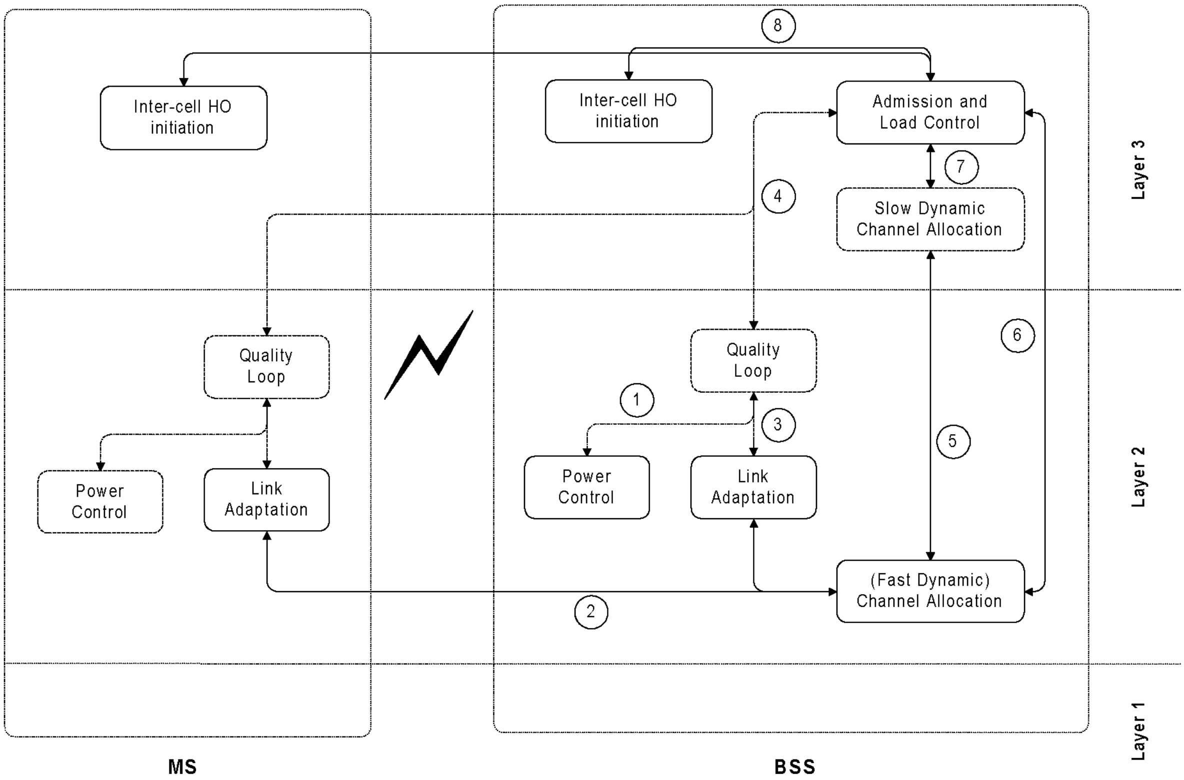



*Figure 5-1. Interactions between algorithms.*

**1. QL ⇔ PC**

The Power Control is C-based and for this kind of PC no Quality Loop is needed. The QL could be needed for C/I based PC which is for further study (if both LA and PC were C/I based then the Quality Loop would take care of the interaction between them).

**2. LA ⇔ fast DCA**

For RT bearers the Link Adaptation functions by changing the number of slots allocated to the bearer. When adapting to the channel conditions the receiving end makes the request to the BS Channel Allocation algorithm and when adapting to the source rate the transmitting end makes the request to the BS Channel Allocation algorithm. The Link Adaptation for NRT bearers is realised by ARQ.

**3. QL ⇔ LA**

The Quality Loop adjusts the LA parameters so that the quality experienced by the bearer is sufficient. The QL is needed only for RT bearers. In this version of the system the adaptive version is not covered and it will be the subject of future studies.

**4. QL ⇔ AC & LC**

The Admission or Load Control may set limits to the C/I target determined by the Quality Loop. This is for further study.

**5. slow DCA ⇔ fast DCA**

The slow DCA determines, in the long term, the channels which the fast DCA can allocate to the bearers.

**6./7. AC & LC ⇔ slow / fast DCA**

The Admission and Load Control algorithms get load and other statistics from the Slow and Fast DCA algorithms. The DCA algorithms get limits to the allocations.

**8. inter-cell HO initiation ⇔ AC & LC**

In the presented C/I based HO algorithm, the loading have an effect on the priorities of the HO candidate cells. If the HO initiation is pathloss based then it has to be separately checked whether the call can be admitted to the desired cell or not.

## 5.3.10 Operation in TDD mode

It is very important for the TDMA UMTS system to be able to function in a TDD mode. This includes asymmetric allocation of capacity in the uplink and downlink directions of transfer. This item is for further study.

## 5.3.11 Bunch concept

Generally in order to control more complex systems like pico- and micro cell environments and exploit the trunking gain, a possibility is to increase the degree of centralisation of the system: the more knowledge the central unit has on the system, the better it can adapt the system to its new situation and optimise the engaged resources. The price for this gain in the co-ordination is on the other hand an increase of the needed information (i.e., signalling and measurements) transfer and important computation resources in the central unit .

In small areas a solution to combine the needs of the coverage with a higher centralisation may be the use of remote antennas. That is the main idea of the ‘bunch’ concept A bunch consists of a limited number of Remote Antenna Units (RAUs) that are connected to a functional entity named Central Unit (CU). All intelligence as well as a significant part of the signal processing are located in the CU. The RAUs are simple antenna units capable of transmitting and receiving user signals as well as performing measurements ordered by the CU (Figure 5-2). A bunch can cover for instance a group of streets, a building or even a building floor.

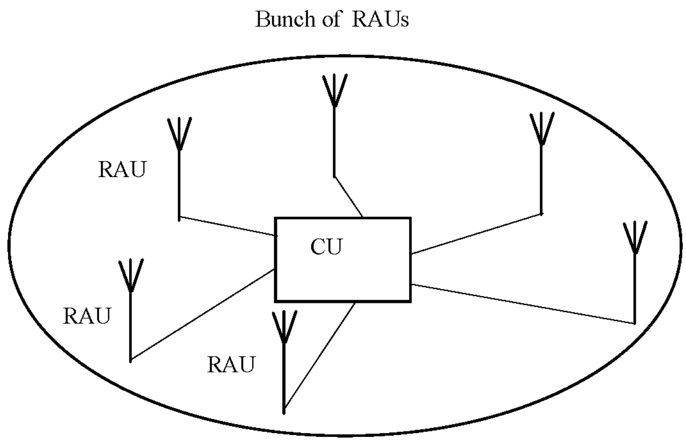



*Figure 5-2: A bunch consists of a Central Unit (CU) and a number of Remote Antenna Units (RAU)*

It is assumed that the RAUs within a bunch are slot and frame synchronised. The relatively short distances between the RAUs and the CU make it feasible to use a high-speed access network and to achieve synchronisation. It should also be possible to exchange information between bunches, but on much lower bandwidth. The advantage of bunches is that they have the potential to offer a high capacity and thus they are ideally suited to hot spot areas. The CU has knowledge about all allocated resources, transmitter powers and path gains in the bunch, and can adaptively allocate resources to the RAUs according to the current need. This results in a very efficient resource utilisation within the bunch. Also, by having a "pool" of resources in the CU, we gain in trunking efficiency An important requirement is that it should be possible to assign resources to RAUs on a slot by slot basis (i.e., individual slots of the same carrier frequency can be assigned to different RAUs). The price for the high capacity is increased algorithm complexity and signalling load.

Bunches are well suited for hot spot applications. In areas with a low capacity demand however, traditional macro cells will probably be used. Hence, bunches must be able to coexist with macro cells as well as with other bunches. Bunches are well suited as the lowest layer in a Hierarchical Cell Structures network (HCS). Figure 5-3 shows a potential scenario, with macro and micro cells, one outdoor bunch and two indoor bunches (each covering a building floor).

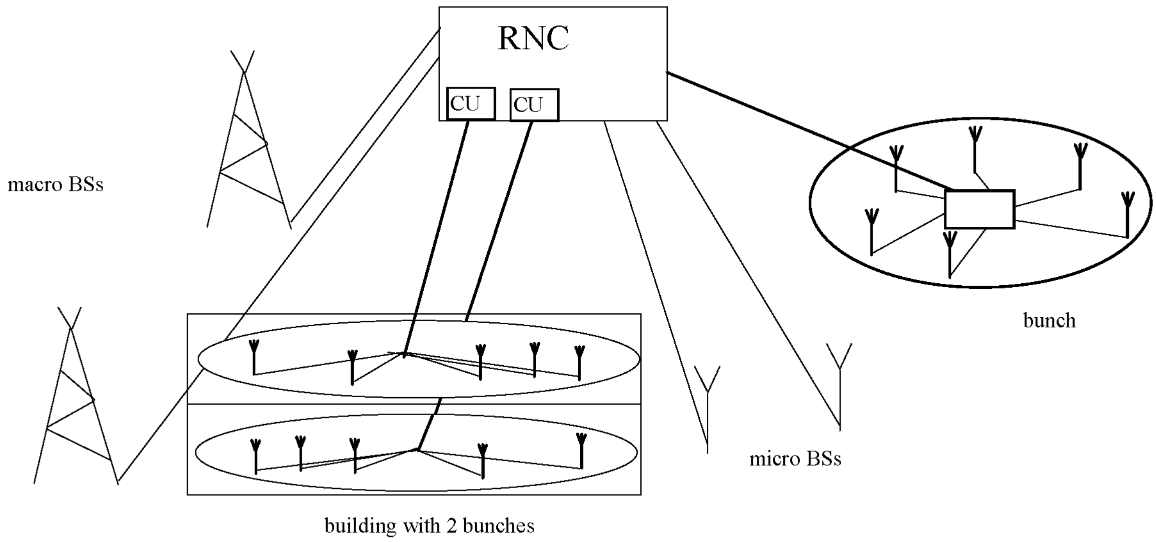



*Figure 5-3: A scenario with several bunches, microcells and macrocells*

In the figure the bunches the micro BS and the macro BS are controlled by a central unit, here denoted RNC (Radio Network Controller). However it should be noted that the Central Unit is only defined from a functional point of view. That means that the different functional CUs may be physically contained in the RNC as long as the requirements put to the physical links between RNC and RAUs are met.

### *5.3.11.1 Overview of algorithms*

There will be two types of interference in the system: intra- and inter-bunch interference. Within a bunch, the synchronism and the centralised approach make it possible to avoid most of the interference by means of sophisticated radio network algorithms. The inter-bunch interference, i.e. from outside the bunch, also needs to be considered. Note that the inter-bunch interference is not only the interference from other bunches but also from cells in other HCS layers.

In this centralised concept, the RRM domains (such as LA and PC) are linked closely together and can not easily be handled separately.

#### 5.3.11.1.1 Inter-bunch algorithms

Between bunches, or between bunches and BSs, random frequency and time hopping can be used to average out the inter-bunch interference, in the same way as between cells in the Interference Averaging concept. All bunches should have individual hopping patterns with low inter-bunch correlation. Using this scheme, we hope to be able to utilise all the operator's frequencies within all bunches (reuse 1 on a bunch level). However, in some scenarios it might be necessary to increase the reuse factor. For example, if the bunch is part of a HCS network, the downlink interference on the bunch from the surrounding macro BSs is likely to be high. Particularly if the bunch uses lower transmit powers than the surrounding network, the situation can be very severe. Therefore, it might become necessary to divide the frequency spectrum so that the bunch uses different frequencies than the nearby macro BSs. Then, frequency and time hopping can only be performed on the part of the spectrum allocated to the bunch or BS. And as soon as frequency planning is needed, there is a need for a slow DCA or similar algorithm that automates this task.

#### 5.3.11.1.2 Intra-bunch algorithms

Also within a bunch, frequency hopping can be used to achieve frequency diversity. The intra-bunch interference is not affected because the hopping is controlled by the CU so that all transmitters maintain the same relative positions in the frequency/time matrix. This means that all transmitters in the bunch hop synchronously, using the same hopping sequence. The resulting constant intra-bunch interference enables the use of algorithms such as fast DCA.

We have integrated all the intra-bunch radio resource management algorithms like channel assignment, link adaptation, power control and handover into a structure that we call Generic Intra-bunch Resource Manager (GIRM). The reason for this is that we believe that the system can be made more efficient if the different algorithms co-operate more tightly than in conventional systems. The intra-bunch algorithms in the bunch concept are highly dependent on each other and thus, they can not be viewed as separate entities. The GIRM consists of a priority queue for requests, one block for allocation of new resources (GA), one for de-allocation of resources (GD), a measurement unit (MMT), a power control entity (PC) which is partly included in the GA and GD. The link adaptation and intra-bunch handover do not have separate blocks because these functions are included in the GA and GD which will be described later.

In some cases, channels can be changed without changing RAU and RAU can be changed without changing channels. This offers the possibility to have MSs in macro diversity (connected to several RAUs at the same time) whenever it is considered appropriate. A natural macro diversity application is "make-before-break" handover, i.e. the MS can be connected to the new RAU before it leaves the old RAU. Another example is a bunch subject to severe interference from outside the bunch. Then, macro diversity could be used to increase the carrier signal strength (C) to improve the MSs' C/I ratio.

## 5.3.12 Frequency management for the multi-band concept

### *5.3.12.1 Frequency split*

In case the system works with several carrier bandwidths, as described in the multi-band concept, a specific frequency management structure is proposed.

Within one cell layer, the total bandwidth allocated to an operator is split into several blocks corresponding to the different carrier bandwidths in use. This arrangement allows to have equal bit rate services in the same part of the total bandwidth and should thus reduce some interference issues between services having different bit rates.

Figure 5.4 shows an example of this structure with a total bandwidth of 8 MHz. The total bandwidth is split into 5 band of 1.6 MHz. Each block of 1.6 MHz is split in bands of 200, 400 or 800 kHz.

The resource split will depend on the service needs. Therefore it should be possible to change it dynamically during the day according to the traffic share between different services. This strategy avoids to allocate important spectrum bandwidth for high bit rate during peak hours for instance.

The resource split must be the same in all cells of the area. In that way, we make sure that a service is always available in the area and we avoid interference between services using different bit rates.

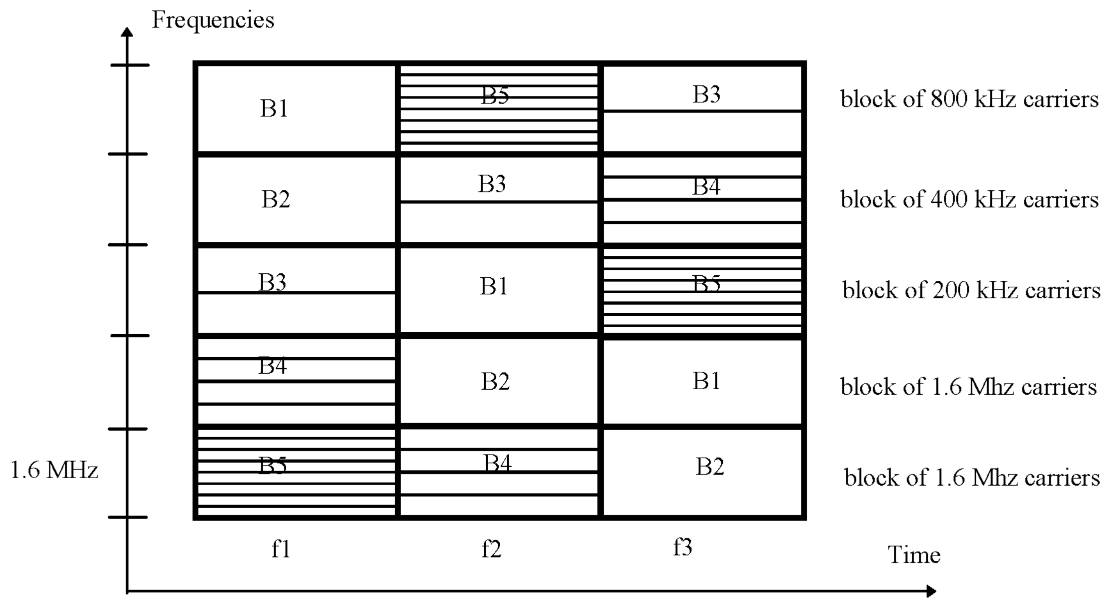



*Figure 5-4 : example of bandwidth structure for one cell layer*

### *5.3.12.2 Frequency hopping algorithm*

Frame by frame frequency hopping can be used with that structure in order to have frequency and interference diversity. Hopping sequence must take into account the frequency structure. It is proposed to use a two-steps frequency hopping algorithm as described below :

The first step is a frequency hopping on the blocks. This hopping sequence is a pseudo-random hopping (we proposed to take the GSM pseudo-random hopping algorithm). In order to keep the same spectrum split for all cells of a given area, the hopping sequence should be the same for each cell of the area. This first step is used in order to have frequency diversity.

The second step is a frequency hopping on sub-bands inside each block. For each block split into sub-bands, a new pseudo-random hopping is applied. This hopping sequence is different for each cell and each block in order to have frequency and interference diversity.

The two steps of the algorithm are independent and the hopping sequences associated also. The second step is optional, and is applied only if the block is split into sub-bands. This algorithm is general enough to be applied by the mobile or the base station. Furthermore, it is flexible enough to support dynamic change of the spectrum split.

For the application of the frequency hopping algorithm, the following parameters are defined and have to be known :

- BlockNb : Number of blocks in the frequency band
- Pmax : Index of the widest carrier bandwidth in the blocks (BW = $2^{Pmax}$ x 100 kHz)
- P : Index of the carrier bandwidth being used (BW = $2^{P}$ x 100 kHz)

The following parameters need also to be known to the mobile or base station when using frequency hopping.

- f : Carrier centre frequency
- Fmin : Minimal frequency of the total bandwidth
- Df : Carrier bandwidth of the elementary carrier (200 kHz)

The term *Random(N)* represents a GSM hopping sequence on N frequencies, with associated parameters HSN and MAIO. For the first step, parameters (HSN, MAIO) are identical for all cells within a given area (no interferer diversity). For the second step, a set of parameters (HSN, MAIO° is associated with each cell.

The following formulas are applied to obtain the new frequency based on the current one :

- first step, pseudo-random hopping on BlockNb blocks :

$$f_{nb} = \left[\frac{f - F_{\min}}{Df} + Random(BlockNb) \times 2^{p\max}\right] \mathrm{mod}(BlockNb \times 2^{p\max})$$

$$f_{new} = F_{\min} + f_{nb} \times Df$$

- second step, pseudo-random hopping within one block, used only if carrier bandwidth in the block is smaller than Pmax :

if ( P < Pmax)

{

$$f_{\min} = F_{\min} + \left[(\mathrm{int})\frac{f_{nb}}{2^{p\max}}\right] \times 2^{p\max} \times Df$$

$$f_{new} = f_{\min} + \left[\left(\frac{f_{nb} \times Df - f_{\min}}{Df} + Random(2^{p\max - p}) \times 2^{p}\right) \mathrm{mod}(2^{p\max})\right] \times Df$$

}

### *5.3.12.3 Resource allocation algorithm*

The resource allocation algorithm needs to be adapted to the multi-band concept, in order to allocate resources, according to the required bit rate and the frequency arrangement.

The algorithm could also have some interaction with the dynamic channel algorithm based on segregation mechanisms, if it is used.

The adaptation of the resource allocation algorithm is currently under study.

### *5.3.12.4 Analysis of the multi-band system concept*

The multi-band system concept has been introduced in section 3.2 as an alternative to the single carrier bandwidth system. Pros and cons of this concept are analysed here to help in the selection of this option.

#### 5.3.12.4.1 Bit rate range for each carrier bandwidth

Each carrier type can support a given range of bit rates. The range of a carrier type is based on the bit rate service supported by one slot and the maximal permitted number of slots allocated on this carrier. An allocation from 1 to Nmax-1 slots per carrier is recommended in order to keep at least one slot for the BCCH channel monitoring process.

The figure 5.5 shows the bit rate range for each carrier type. If we consider a certain bit rate, this figure shows which carrier type can support this bit rate. The resource allocation strategy may favour either the allocation of a few slots on a wide bandwidth or the allocation of a lot of slots on smaller bands.

For example, the 200 kHz band can support 11,7 kbits/s up to 182 kbits/s gross bit rate. The first one is obtained by using one 1/16 slot in a frame, and the last one is obtained by using 7 1/8 slots in a frame.

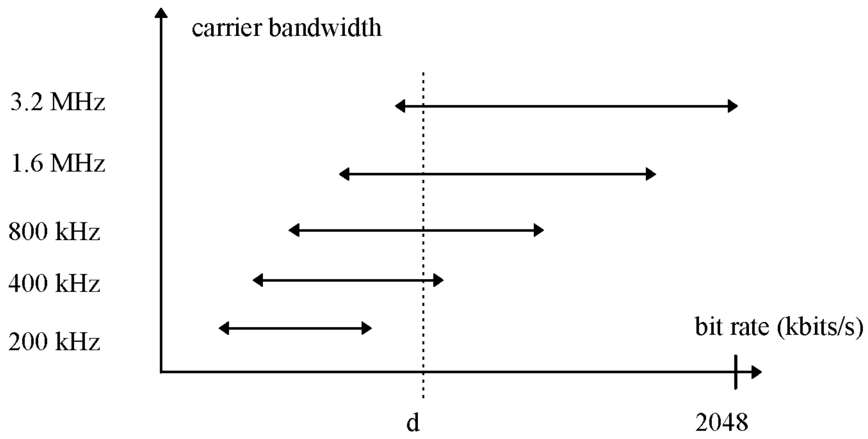



*Figure 5-5 : bit rate range for each carrier type*

#### 5.3.12.4.2 Pros and cons for the multi-band concept

The following advantages have been identified for the multi-band concept :

- This concept permits to optimise the TDMA transmission scheme for all envisaged bit rates and environments. Such an optimisation is not feasible with a single bandwidth.
- With this concept, low bit rate terminals may only use small bandwidth option, thus reducing complexity and cost. This multi-band concept allows to propose several mobile terminals, according to the offered services. Thus, a very cheap terminal could be proposed for speech services and some low bit rate data services.
- Migration from GSM to UMTS will be easy with this approach, since 200 kHz bands could be used with GSM modulation.
- The handover between Multi-band TDMA and GSM may be very easy if the control channels are mapped on 200 kHz frequencies. Indeed, this allows to listen transparently to GSM or Multi-band TDMA beacon frequencies.
- The flexibility of the frequency structure will allow to dynamically adapt the configuration according to traffic needs.
- The multiband concept need less overhead (due to guard time and training period), compared to the wideband TDMA burst structure.

However the following problems have also been identified and would need further studies :

- The multi-band concept implies that a mobile terminal can be configured with several carrier bandwidths, depending on the carrier type in use.
- In the base station, for an efficient adaptation to traffic needs, it should be possible to dynamically change the frequency split between the different carrier types, without any change in the number of TxRx. Therefore, these TxRx should be able to transmit using a single 1.6 MHz carrier or using 8 200 kHz carriers (with different mobiles). This requirement puts high constraints on RF parts in base station that need to be evaluated.
- The resource allocation mechanisms will be slightly more complex than in the case of a single carrier bandwitdth for an optimal use of radio resources.
- Interference between adjacent channels of different bandwidth may occur and this will also need further studies.

#### 5.3.12.4.3 Provisional conclusion

From a pure performance point of view, the multi-band system concept seems to provide interesting improvement compared to the single bandwidth system. However more detailed evaluation results are needed to estimate the trade-off between performance and complexity/cost. Also this concept could be used as an option according to the expected environment and services.

Finally, the exact definition of carrier bandwidth and frames structure might need to be reviewed at a later stage, whenever this concept is retained for UTRA.

### *5.4 Conclusion of the RRM techniques*

The IA concept is proposed to be the basic RRM scheme and the Bunch concept may be used in some areas where the traffic load is high. However, these concepts are just examples of a wide range of RRM schemes that can be supported with the flexible signalling designed for these concepts. E.g. the Power Control strategy ensures the possibility to use slow, fast or packet based Power Control. The PC criteria can also be changed (according to quality, RSSI etc.). Different RRM strategies can then utilise the most suitable PC strategy. Also different services may utilise different PC strategies. Further, the Quality Loop can adapt the target of the C/I based LA or PC or both.

# 6. Enhancements

The simulation results of WB-TDMA are shown in Chapter 7. These performance results can be improved in a number of ways. A few possible enhancements are discussed in this chapter.

## *6.1 Utilisation of the reciprocal channel for TDD operation*

In TDD operation the fast fading is the same both in uplink and downlink if the Doppler frequency is sufficiently lower than the frame frequency. This reciprocal channel can be utilised for

- open loop control
- transmission diversity

## *6.2 Adaptive antennas (AA)*

The well-known advantages of adaptive antennas system are following

- improved range
- improved spectrum efficiency
- improved quality

Without doubt, the amount improvement which AA techniques provide, depends on the antenna array complexity. As AA techniques are often more powerful when used in the receiver side, the possibility of implementing a small antenna array in the mobile receiver is of interesting alternative in the WB-TDMA system to balance the up- and downlink performances.

The WB-TDMA system is designed to well support the usage of adaptive antennas. For example, appropriate training sequences with good cross-correlation are selected to optimise the usage of AA techniques for interference cancellation. The implementation of BCCH in the system taking advantage of AA techniques requires also careful system design as BCCH by its omni-directional nature makes it difficult to support adaptive antennas. In Sec. 2.5, the discontinuous BCCH on WB-carrier allows to use AA techniques in the TCH channels located on the same carrier with BCCH carrier and range extension for BCCH can be achieved by adding sufficient amount of redundancy on BCCH information. The other alternative, 200 kHz continuous BCCH has a better range inherently as a consequence of its narrower bandwidth.

Interference cancellation by using digital antenna array implemented in the receiver is a very powerful technique against co-channel interference as well as other spatially distributed interferences such as adjacent channel interference. The system requirements for AA-IC-receiver are not as stringent as for the JD-receiver. For example, AA-IC-receiver do not strictly require synchronous system. A drawback of asynchronism is that the interference is not the same over a burst which leads to gradual performance loss if the interference cannot be estimated separately for the both ends of a burst. In the synchronous system, the optimisation of training sequence cross-correlation properties is of key importance.

## *6.3 Antenna diversity*

All capacity results shown in this document are for downlink without antenna diversity. Since antenna diversity could be applied in the uplink, a considerable improvement could be expected compared to these downlink results.

## *6.4 Inter-cell interference suppression*

At least two types of interference cancellation techniques are applicable in WB-TDMA system: joint demodulation of co-channel signals and adaptive antennas. Interference cancellation (IC) is referred technique which implemented in the receiver to suppress the interference which is present in the receiver. This can be done in real time by post-processing the burst in the receiver memory.

The advantages of co-channel inter-cell interference suppression in WB-TDMA are as follows

- improved spectrum efficiency (lower reuse, or saved air interface time)

- easier cell deployment
- improved quality
- make the receivers operation more reliable in the case of sudden interference changes

The first bullet refers to the capacity increase resulting from the receivers' improved susceptibility with co-channel interference. A way to gain the capacity is to design the network with lower reuse when IC-receivers are used. Another way not requiring lowering the reuse factor, is to take advantage of the saved air time as the IC-receiver copes with less channel coding and/or retransmission.

The second bullet implies the possibility to rely on IC as a method to equalise the location dependent interference level changes. An example of such case is a street micro-cellular system where street crossings suffer from a higher interference level. Already, fast link adaptation is specified in WB-TDMA system to tackle the same problem, but at the expense of extra radio resources.

The third bullet, implies the possibility to provide a better service quality for a user having receiver with IC-capability. For example, a user with IC-receiver may be granted with a higher service bit rate as it can cope with less channel coding.

The fourth bullet emphasises the fact that interference cancellation can be thought as real-time adaptation as it removes the interference which already were present in the receiver. If the receiver can adapt the sudden interference level changes, it helps e.g. to avoid call drop outs or extra time can be obtained to perform handover to a new base station or channel.

## *6.5 Joint demodulation of co-channel signals*

In TDMA systems, as the number of nearby co-channel signals is few and the signals have independent propagation paths, there is a high probability for the existence of a dominant interfering signal (DI) in the receiver. The probability of DI is further increased by DTX, fractional loading and cell sectorisation. Joint demodulation of desired signal and DI provides substantial interference suppression gain and, moreover, makes it feasible to implement a receiver with reasonable complexity.

The receiver can divided into two parts: joint channel estimator and detector. From the detector complexity and structure point of view, detection of two independent Bin OQAM signals simultaneously is identical to the detection of a single Quat-OQAM signal. Therefore, as Quat-OQAM is supported anyway by WB-TDMA receiver, the support of IC for Bin-OQAM signals do not require major changes in the demodulator. The practical limitations of receiver complexity limits the operational environment of the JD-receiver as for Quat-OQAM modulation

To support joint channel estimation and DI identification, base stations need to be synchronised to make training sequences from co-channels overlap with each other and training sequences with good cross-correlation properties need to be used.

## *6.6 Improved Modulation and channel coding*

In principle the W-TDMA concept can support any modulation scheme meeting the emission mask requirements. This will allow the use of higher order modulations to support even higher bit rate connections over short ranges (e.g., within a single room). It will also allow alternative methods of combating multipath, such as OFDM.

Similarly, the use of different channel coding algorithms need not be restricted. By optimised the channel coding the link levels performance and system capacities can be improved. The following items are examples for improving the channel coding.

- optimised puncturing
- Turbo codes
- longer constraint lengths, now $K$=5 for convolutional codes and $K$=3 for Turbo codes
- Interleaving depth can be adjusted to optimise trade off between bearer C/I requirement and delay

Finally, the multi-band concept could be extended to consider wider bandwidths, which would allow higher bit rates to be supported. Available spectrum is likely to be a constraint on evolution in this direction.

## *6.7 Fast power control (frame-by-frame)*

Fast power control (frame-by-frame) could be used to improve the performance in case where frequency hopping cannot be applied. Such case is e.g. if the operator has only one carrier available.

# 7. Simulations

## *7.1 Simulation cases*

*Table 1. Simulation cases*

| Priority | Environment | Service | Propagation model | Cell coverage | Link level | System level |
|---|---|---|---|---|---|---|
| 1.1 | Outdoor to Indoor and Pedestrian 3 km/h | UDD 384 | Outdoor to Indoor and Pedestrian A | Microcell | X | X |
| 1.2 | | Speech | | | X | X |
| 1.3 | | LCD 144 kbit/s | | | X | |
| 1.5 | | UDD 2048 | | | X | |
| 2.1 | Indoor 3 km/h | UDD 2048 | Indoor A | Picocell | X | X |
| 2.2 | | Speech | | | X | |
| 2.3 | | LCD 384 kbit/s | | | X | |
| 2.4 | | 50 % speech + 50 % UDD 384 | | | | X |
| 3.1 | Vehicular 120 km/h | UDD 144 | Vehicular A | Macrocell | X | |
| 3.2 | | Speech | | | X | X |
| 3.3 | | LCD 384 kbit/s | | | X | X |

*Table 2. Description of simulation cases*

| Test environments | Indoor Office | Outdoor to Indoor and Pedestrian | Vehicular 120 km/h | Vehicular 500 km/h |
|---|---|---|---|---|
| **Test services** | bit rates (values)<br>BER<br>Channel activity | bit rates (values)<br>BER<br>Channel activity | bit rates (values)<br>BER<br>Channel activity | bit rates (values)<br>BER<br>Channel activity |
| **Representative low delay data bearer for speech*1** | 8 kbps<br>$\leq 10^{-3}$<br>20 ms<br>50% | 8 kbps<br>$\leq 10^{-3}$<br>20 ms<br>50% | 8 kbps<br>$\leq 10^{-3}$<br>20 ms<br>50% | 8 kbps<br>$\leq 10^{-3}$<br>20 ms<br>50% |
| **LDD Data (circuit-switched, low delay)*1** | 144-384-2048 kbps<br>$\leq 10^{-6}$<br>50 ms<br>100% | 64 - 144 - 384 kbps<br>$\leq 10^{-6}$<br>50 ms<br>100% | 32 - 144 - 384 kbps<br>$\leq 10^{-6}$<br>50 ms<br>100% | 32 -- 144 kbps<br>$\leq 10^{-6}$<br>50 ms<br>100% |
| **LCD Data (circuit-switched, long delay constrained)*1** | 144-384-2048 kbps<br>$\leq 10^{-6}$<br>300 ms<br>100% | 64 - 144 - 384 kbps<br>$\leq 10^{-6}$<br>300 ms<br>100% | 32 - 144 - 384 kbps<br>$\leq 10^{-6}$<br>300 ms<br>100% | 32 - - 144 kbps<br>$\leq 10^{-6}$<br>300 ms<br>100% |
| **UDD Data (packet) Connection-less information types** | See section 1.2.2 | See section 1.2.2 | See section 1.2.2 | See section 1.2.2 |

*1 Proponents must indicate the achieved one-way delay (excluding propagation delay, delay due to speech framing and processing delay of voice channel coding) for all the test services.

Note : For LDD services, a BER threshold of $10^{-4}$ will be considered for the initial comparison phase of the different concepts in order to reduce simulation times. The BER threshold of $10^{-6}$ will be considered in the optimization phase.

## *7.2 Introduction*

This document presents link level simulation results of FMA1 without spreading (WB-TDMA). The results are obtained with COSSAP. Both non-real time service results with ARQ and real time service results with FEC are presented. For Real time (RT) services the interference averaging concept relies heavily on the link adaptation. Therefore a few link adaptation options are presented for RT services. For providing input to system simulations the link level simulations are run against one co-channel interferer and for range calculations against Gaussian noise. These results are valid both for FDD and

TDD operation. In TDD operation, however, these results could be improved by utilising the reciprocal channel for e.g. open loop control and transmission diversity.

The results in this document are shown against average(C)/average(I). The interface between link and system level simulations does not directly utilise these curves but the burst-by-burst collected information. For more information about the interface see the following chapter and [16]

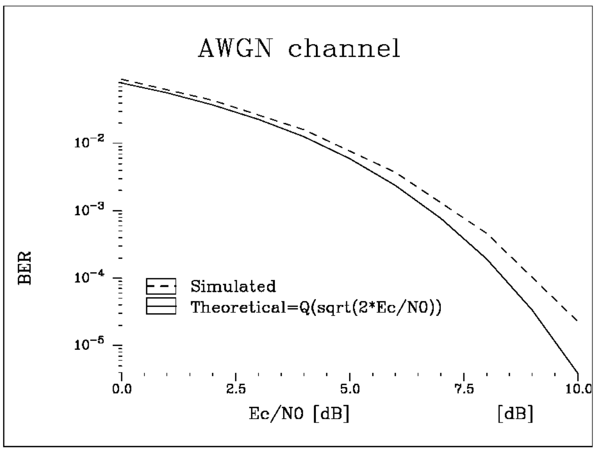
The basic assumptions and technical choices of the link level simulations are shown in Table 7-1.

*Table 7-1. Link level assumptions and technical choices*

| | |
|---|---|
| **Channel estimator** | Correlator, delay search window of 3 symbols,<br>independent estimation from burst-to-burst |
| **Equaliser** | Soft Output Viterbi Algorithm (SOVA) |
| **Number of equaliser taps** | ITU Indoor A: 3 taps<br>ITU Outdoor to indoor A: 3 taps<br>ITU Vehicular A/B: 5 taps |
| **Modulation** | Bin-O-QAM<br>Quat-O-QAM |
| **Channel coding** | Convolutional codes, $K$=5, K=9<br>Turbo codes, $K$=3<br>+ puncturing / repetition for rate matching<br>Concatenated code for LCD 144 and LCD 384: Reed-Solomon (500,400) or Reed-Solomon (210,168) + Convolutional code ($K=9$) |
| **Power control** | Slow power control, not modelled in link level |
| **Interference modelling** | One co-channel interferer (for capacity)<br>Gaussian noise (for range) |
| **Antenna diversity** | In uplink, not in downlink |
| **Frequency hopping** | Frame-by-frame hopping or slot-by-slot hopping<br>Uncorrelated frequencies |
| **Time hopping** | Included in link level frequency hopping for interference diversity, not separately modelled in link level |

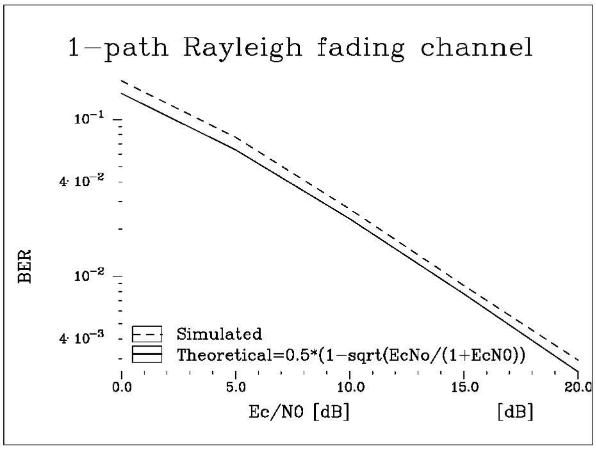
## *7.3 Validation of simulation chains*

The link level COSSAP simulation chains of FMA1 without spreading has been validated by comparing the simulation results in non-fading AWGN channel and in 1-path Rayleigh fading channel to the theoretical BER-curves. The results are shown in the figure below.




Simulated results compared to theoretical value in AWGN channel

(overhead due to training sequence and tail bits is not to be taken into account in Ec/No)




Simulated results compared to theoretical value in 1-path Rayleigh fading channel

The simulated results are a little worse than theoretical values as expected. This is due to the non-ideal channel estimation.

## *7.4 Required $E_b/N_0$'s and C/I's*

### 7.4.1 Speech

| **Required $E_b/N_0$ (dB) for speech** | **1 slot/frame** UL/DL | **2 slots/frame** UL/DL | **4 slots/frame** UL/DL | **6 slots/frame** UL/DL |
|---|---|---|---|---|
| Indoor_A 3 km/h | 6.9 / 12.4 | 5.5 / 9.8 | 5.6 / 8.6 | 5.9 / 8.4 |
| Micro_A 3 km/h | 6.9 / 12.2 | 5.7 / 9.7 | 5.6 / 8.7 | 5.9 / 8.6 |
| Vehicular_A 120 km/h | 6.6 / 11.6 | 6.2 / 9.6 | 6.2 / 8.9 | 6.6 / 8.7 |
| Vehicular_B 120 km/h | 8.6 / 18.8 | 7.1 / 11.2 | 6.9 / 9.7 | 7.1 / 9.5 |
| Vehicular_B 250 km/h | 8.6 / 19.6 | 7.1 / 11.7 | 6.9 / 10.1 | 7.2 / 9.5 |

| **Required C/I (dB) for speech** | **1 slot/frame** UL/DL | **2 slots/frame** UL/DL | **4 slots/frame** UL/DL | **6 slots/frame** UL/DL |
|---|---|---|---|---|
| Indoor_A 3 km/h | 2.0 / 7.5 | -2.9 / 1.7 | -6.8 / -2.8 | -9.0 / -5.1 |
| Micro_A 3 km/h | 1.8 / 7.9 | -3.1 / 1.7 | -6.8 / -3.2 | -8.7 / -5.3 |
| Vehicular_A 120 km/h | 2.0 / 7.7 | -1.9 / 2.2 | -5.3 / -1.9 | -7.0 / -4.1 |
| Vehicular_B 120 km/h | 3.9 / 13.0 | -0.7 / 4.2 | -4.7 / -0.9 | -6.3 / -3.2 |
| Vehicular_B 250 km/h | 4.0 / 15.0 | -0.7 / 4.6 | -4.6 / -0.8 | -6.4 / -3.0 |

### 7.4.2 UDD

| **Required $E_b/N_0$ (dB) for UDD 144** | **2 slot/frame** UL/DL | **4 slots/frame** UL/DL |
|---|---|---|
| Indoor_A 3 km/h | 2.7 / 6.3 | 2.3 / 4.9 |
| Micro_A 3 km/h | 2.8 / 6.2 | 2.1 / 4.9 |

| | | |
|---|---|---|
| Vehicular_A<br>120 km/h | 4.0 / 8.1 | 3.2 / 6.2 |
| Vehicular_B<br>120 km/h | - / 11.0 | - / 7.2 |
| Vehicular_B<br>250 km/h | 5.2 / 11.3 | 3.7 / 7.1 |

| **Required C/I (dB) for UDD 144** | **2 slot/frame**<br>UL/DL | **4 slots/frame**<br>UL/DL | **8 slots/frame**<br>UL/DL |
|---|---|---|---|
| Indoor_A<br>3 km/h | -1.6 / 2.1 | -6.5 / -3.8 | - / - |
| Micro_A<br>3 km/h | -1.5 / 2.3 | -6.2 / -3.7 | - / -8.0 |
| Vehicular_A<br>120 km/h | 0.9 / 4.7 | -3.4 / -1.1 | - / -5.1 |
| Vehicular_B<br>120 km/h | - / 8.7 | - / 0.8 | - / -3.7 |
| Vehicular_B<br>250 km/h | 2.7 / 8.9 | -2.5 / 0.6 | -5.6 / -3.7 |

| **Required $E_b/N_0$ (dB) for UDD 384** | **8 slots/frame**<br>UL/DL | **16 slots/frame**<br>UL/DL |
|---|---|---|
| Indoor_A<br>3 km/h | 2.1 / 5.1 | 2.4 / 4.9 |
| Micro_A<br>3 km/h | 2.0 / 5.2 | 2.3 / 4.9 |
| Vehicular_A<br>120 km/h | 3.4 / 6.6 | 3.4 / 6.2 |
| Vehicular_B<br>120 km/h | - / 8.0 | - / 6.9 |
| Vehicular_B<br>250 km/h | 4.1 / 7.9 | 3.8 / 6.6 |

| **Required C/I (dB) for UDD 384** | **8 slots/frame**<br>UL/DL | **12 slots/frame**<br>UL/DL | **16 slots/frame**<br>UL/DL |
|---|---|---|---|
| Indoor_A<br>3 km/h | -4.6 / -1.8 | - / - | - / - |
| Micro_A<br>3 km/h | -4.6 / -1.5 | - / - | - / -6.5 |
| Vehicular_A<br>120 km/h | -1.8 / 1.0 | -3.8 / -1.8 | - / -2.9 |
| Vehicular_B<br>120 km/h | - / 2.8 | - / -0.3 | - / -2.0 |
| Vehicular_B<br>250 km/h | -0.7 / 3.0 | -4.3 / -0.3 | -3.1 / -2.1 |

| **Required $E_b/N_0$ (dB) for UDD 2048** | **16 slots/frame**<br>UL/DL |
|---|---|
| Indoor_A<br>3 km/h | 4.6 / 7.0 (Quat!) |
| Micro_A<br>3 km/h | 4.4 / 7.6 (Quat!) |
| Vehicular_A<br>120 km/h | 12.7 / 16.9 |

| | |
|---|---|
| Vehicular_B<br>120 km/h | not possible |
| Vehicular_B<br>250 km/h | - / - |

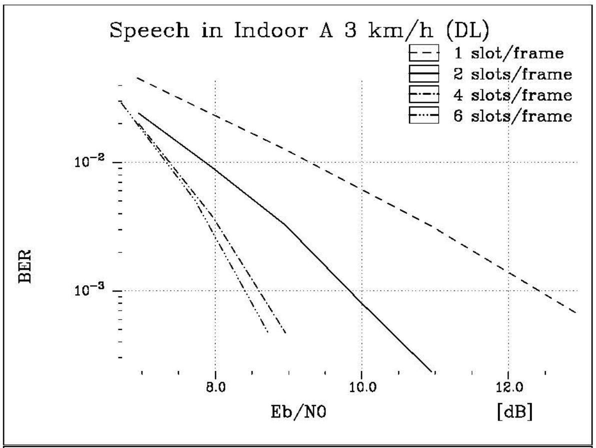
| **Required C/I (dB) for UDD 2048** | **16 slots/frame**<br>UL/DL |
|---|---|
| Indoor_A<br>3 km/h | 4.2 / 7.6 (Quat!) |
| Micro_A<br>3 km/h | 4.3 / 8.2 (Quat!) |
| Vehicular_A<br>120 km/h | 12.2 / 17.6 |
| Vehicular_B<br>120 km/h | not possible |
| Vehicular_B<br>250 km/h | not possible |

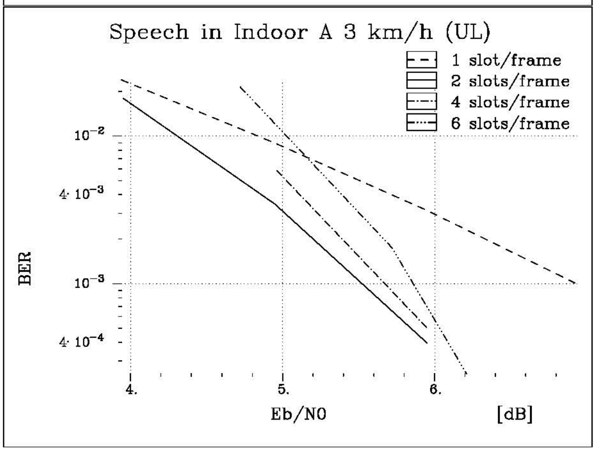
## *7.5 $E_b/N_0$ simulation results*

### 7.5.1 Speech

#### *7.5.1.1 Speech in ITU Indoor_A*

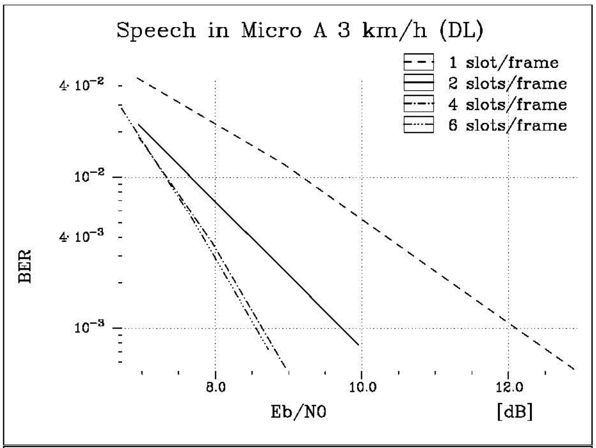
| **Parameters** | **Value(s)** |
|---|---|
| Slot size | 1/64 |
| Modulation(s) | Bin-O-QAM |
| Number of slots used per frame | 1, 2, 4, 6 |
| Uncoded data block | 150 |
| Coding rate | 0.26, 0.13, 0.07, 0.05 |
| Basic code | CC(1,2,9) |
| Interleaving depth | Over 4 frames |
| Puncturing | Yes |
| Frequency hopping | Yes |
| Mobile speed | 3 km/h |
| Antenna diversity | DL: No, UL: Yes |

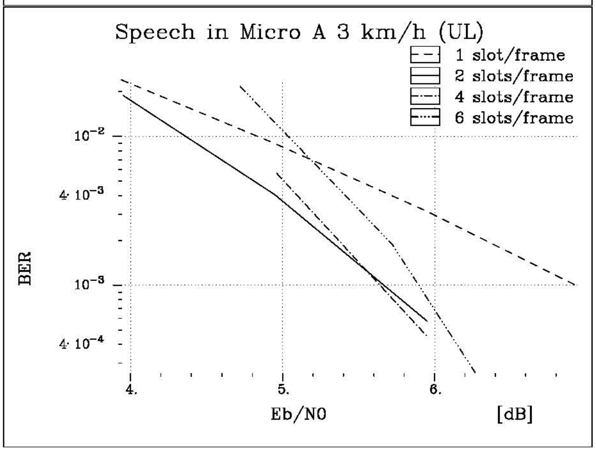



### *7.5.1.2 Speech in ITU Micro_A*

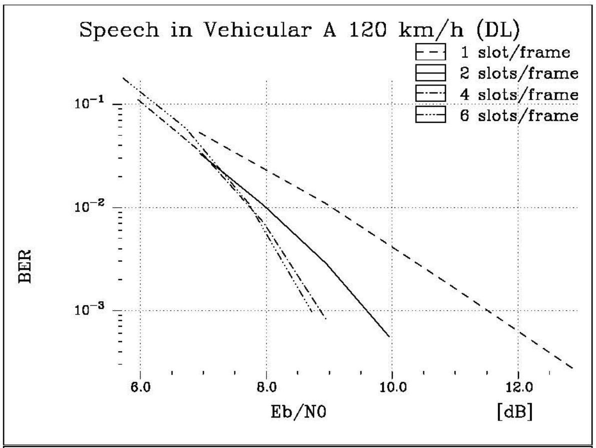
| Parameters | Value(s) |
|---|---|
| Slot size | 1/64 |
| Modulation(s) | Bin-O-QAM |
| Number of slots used per frame | 1, 2, 4, 6 |
| Uncoded data block | 150 |
| Coding rate | 0.26, 0.13, 0.07, 0.05 |
| Basic code | CC(1,2,9) |
| Interleaving depth | Over 4 frames |
| Puncturing | Yes |
| Frequency hopping | Yes |
| Mobile speed | 3 km/h |
| Antenna diversity | DL: No, UL: Yes |

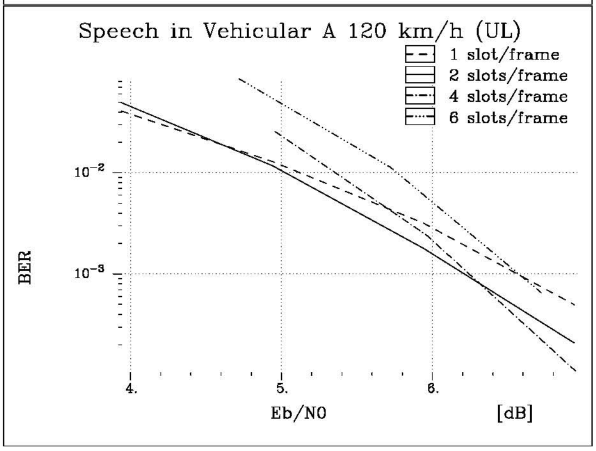



### 7.5.1.3 Speech in ITU Vehicular_A

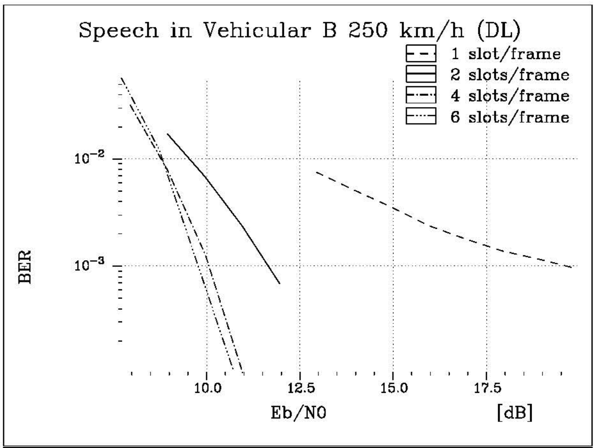
| Parameters | Value(s) |
|---|---|
| Slot size | 1/64 |
| Modulation(s) | Bin-O-QAM |
| Number of slots used per frame | 1, 2, 4, 6 |
| Uncoded data block | 150 |
| Coding rate | 0.26, 0.13, 0.07, 0.05 |
| Basic code | CC(1,4,9) |
| Interleaving depth | Over 4 frames |
| Puncturing | Yes |
| Frequency hopping | Slot-by-slot |
| Mobile speed | 120 km/h |
| Antenna diversity | DL: No, UL: Yes |

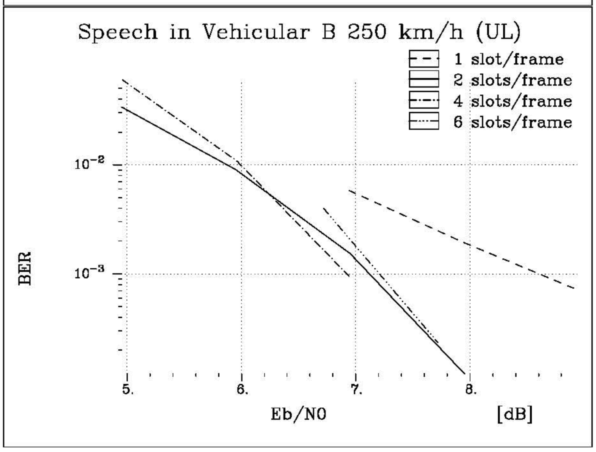



### *7.5.1.4 Speech in ITU Vehicular_B*

| Parameters | Value(s) |
|---|---|
| Slot size | 1/64 |
| Modulation(s) | Bin-O-QAM |
| Number of slots used per frame | 1, 2, 4, 6 |
| Uncoded data block | 150 |
| Coding rate | 0.26, 0.13, 0.07, 0.05 |
| Basic code | CC(1,4,9) |
| Interleaving depth | Over 4 frames |
| Puncturing | Yes |
| Frequency hopping | Slot-by-slot |
| Mobile speed | 250 km/h |
| Antenna diversity | DL: No, UL: Yes |

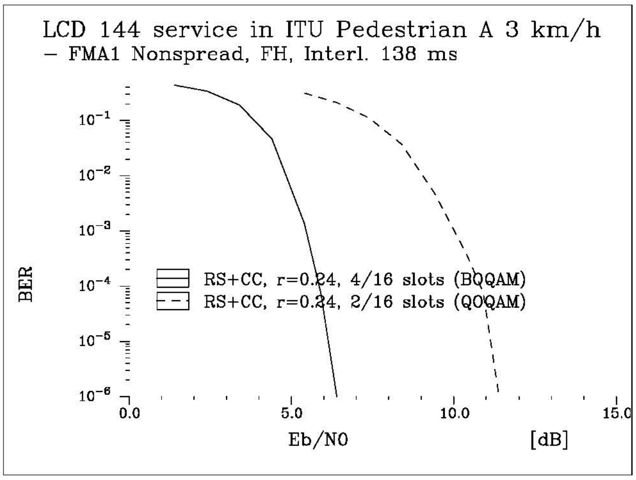



### 7.5.2 LCD

#### *7.5.2.1 LCD 144 in ITU Micro_A*

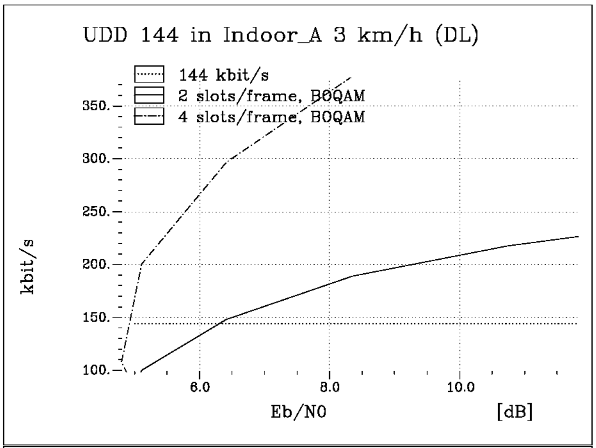
| Parameters | Value(s) |
|---|---|
| Slot size | 1/16 |
| Modulation(s) | Quat-O-QAM, Bin-O-QAM |
| Number of slots used per frame | 2,4 |
| User bitrate | 145.6 kbit/s |
| Coding rate | 0.24 |
| Basic code | CC(1,2,5), RS-code |
| Interleaving depth | Over 30 frames |
| Puncturing | Yes |
| Frequency hopping | Slot-by-slot |
| Mobile speed | 3 km/h |
| Antenna diversity | No |

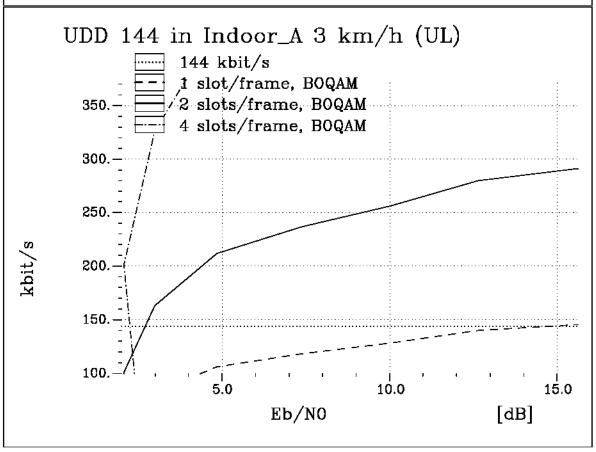


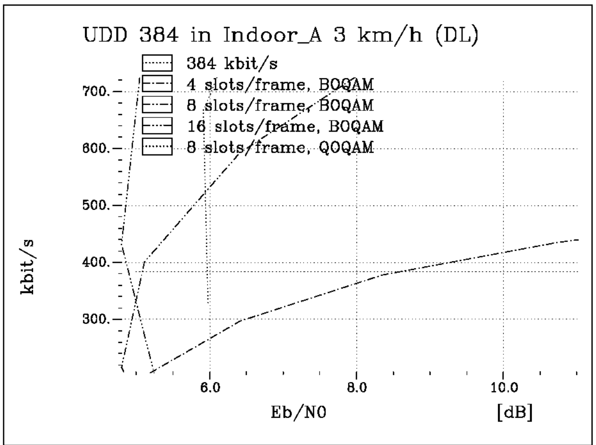

## 7.5.3 UDD

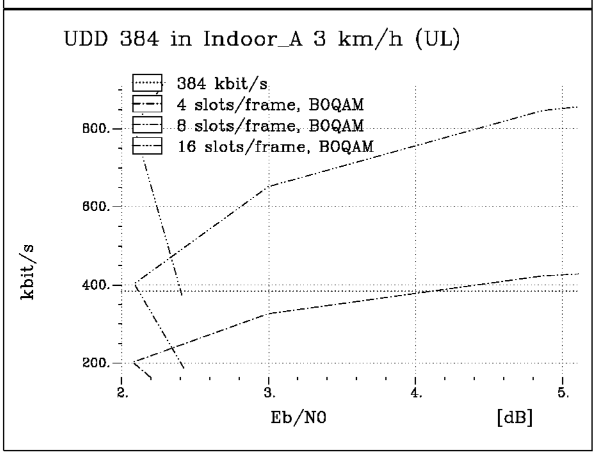
### *7.5.3.1 UDD in ITU Indoor_A*

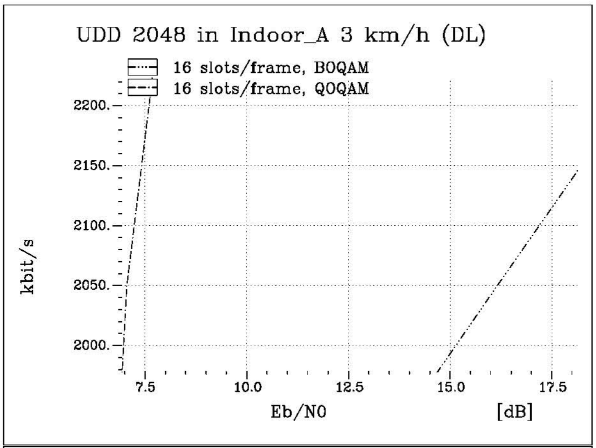
| Parameters | Value(s) |
| --- | --- |
| Slot size | 1/16 |
| Modulation(s) | Bin-O-QAM and Quat-O-QAM |
| Number of slots used per frame | 2, 4, 8, 16 |
| Uncoded data block | 2726 |
| Coding rate | Variable |
| Basic code | CC(1,29) |
| Interleaving depth | Over 4 or 8 bursts |
| Puncturing | Via hybrid-ARQ |
| Frequency hopping | Slot-by-slot |
| Mobile speed | 3 km/h |
| Antenna diversity | UL: Yes, DL: No |

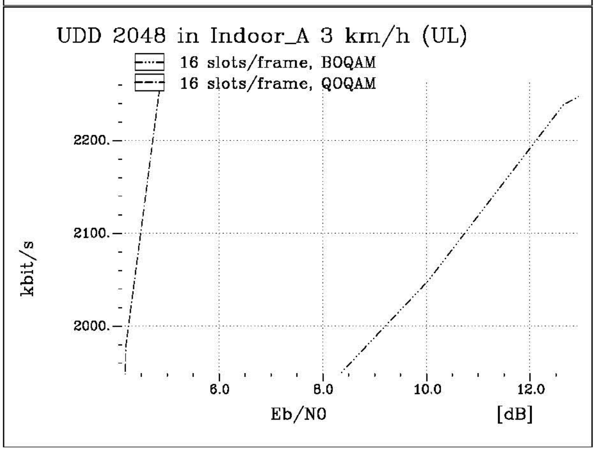

UDD 144 in Indoor_A 3 km/h (DL)
144 kbit/s
2 slots/frame, BOQAM
4 slots/frame, BOQAM
kbit/s
100.
150.
200.
250.
300.
350.
6.0
8.0
10.0
Eb/N0
[dB]


UDD 144 in Indoor_A 3 km/h (UL)
144 kbit/s
1 slot/frame, BOQAM
2 slots/frame, BOQAM
4 slots/frame, BOQAM
kbit/s
100.
150.
200.
250.
300.
350.
5.0
10.0
15.0
Eb/N0
[dB]


UDD 384 in Indoor_A 3 km/h (DL)
384 kbit/s
4 slots/frame, BOQAM
8 slots/frame, BOQAM
16 slots/frame, BOQAM
8 slots/frame, QOQAM
kbit/s
300.
400.
500.
600.
700.
6.0
8.0
10.0
Eb/N0
[dB]

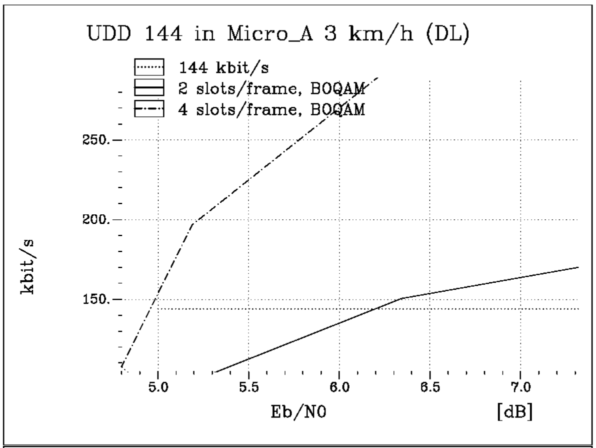

UDD 384 in Indoor_A 3 km/h (UL)
384 kbit/s
4 slots/frame, BOQAM
8 slots/frame, BOQAM
16 slots/frame, BOQAM
kbit/s
200.
400.
600.
800.
2.
3.
4.
5.
Eb/N0
[dB]

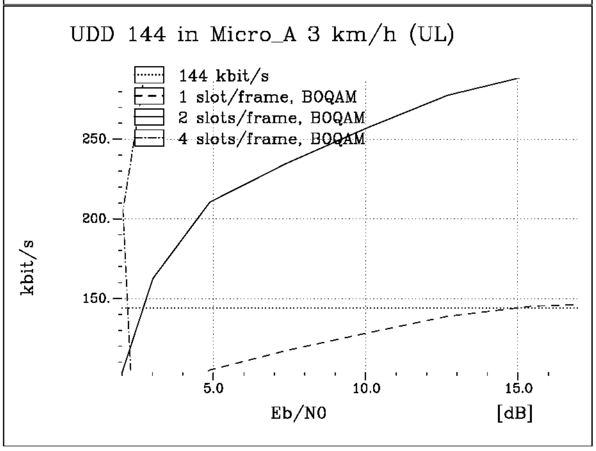


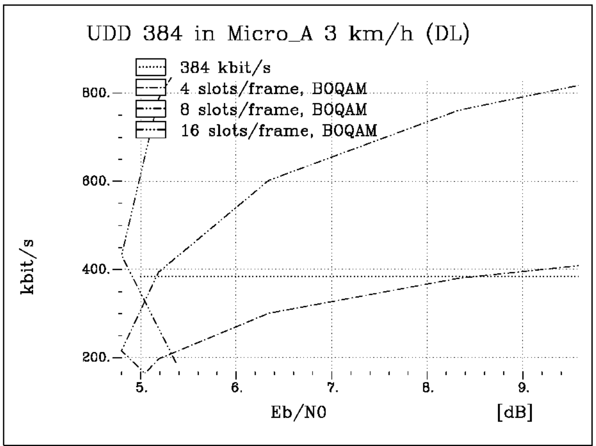



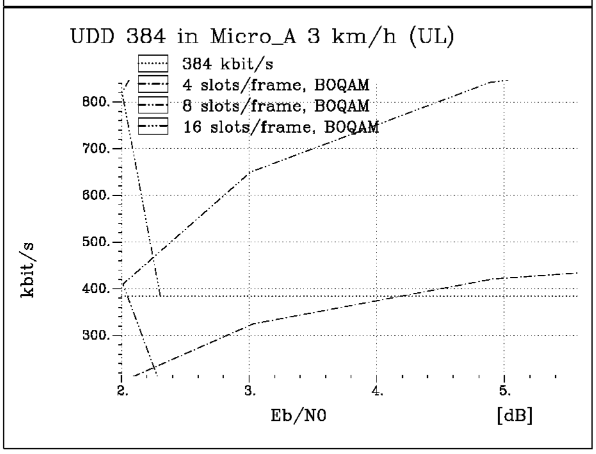

### *7.5.3.2 UDD in ITU Micro_A*

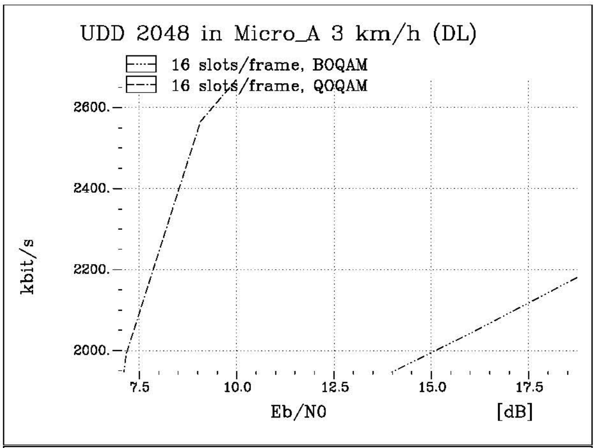
| Parameters | Value(s) |
|---|---|
| Slot size | 1/16 |
| Modulation(s) | Bin-O-QAM and Quat-O-QAM |
| Number of slots used per frame | 2, 4, 8, 16 |
| Uncoded data block | 2726 |
| Coding rate | Variable |
| Basic code | CC(1,29) |
| Interleaving depth | Over 4 or 8 bursts |
| Puncturing | Via hybrid-ARQ |
| Frequency hopping | Slot-by-slot |
| Mobile speed | 3 km/h |
| Antenna diversity | UL: Yes, DL: No |

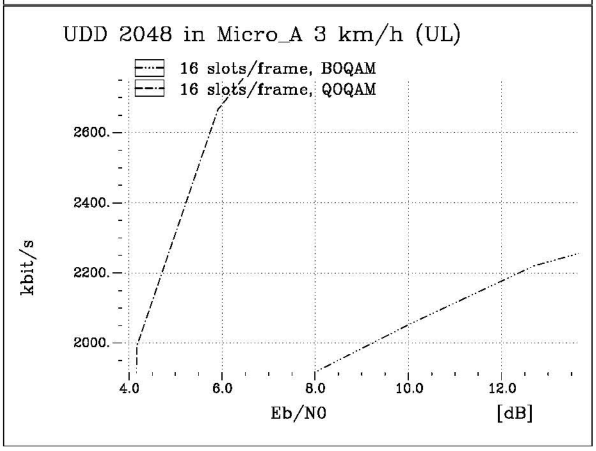

UDD 144 in Micro_A 3 km/h (DL)
144 kbit/s
2 slots/frame, BOQAM
4 slots/frame, BOQAM
kbit/s
Eb/N0
[dB]


UDD 144 in Micro_A 3 km/h (UL)
144 kbit/s
1 slot/frame, BOQAM
2 slots/frame, BOQAM
4 slots/frame, BOQAM
kbit/s
Eb/N0
[dB]


UDD 384 in Micro_A 3 km/h (DL)
384 kbit/s
4 slots/frame, BOQAM
8 slots/frame, BOQAM
16 slots/frame, BOQAM
kbit/s
Eb/N0
[dB]

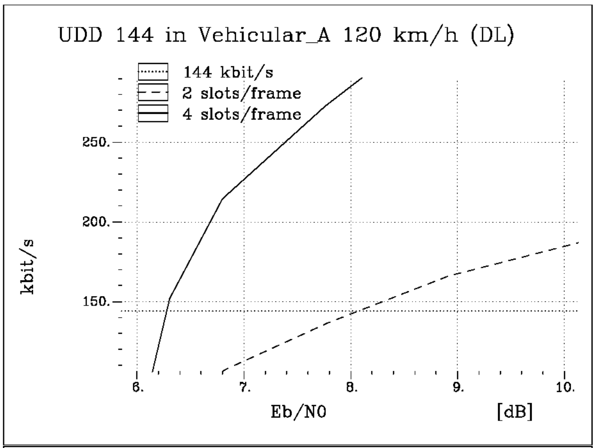

UDD 384 in Micro_A 3 km/h (UL)
384 kbit/s
4 slots/frame, BOQAM
8 slots/frame, BOQAM
16 slots/frame, BOQAM
kbit/s
Eb/N0
[dB]

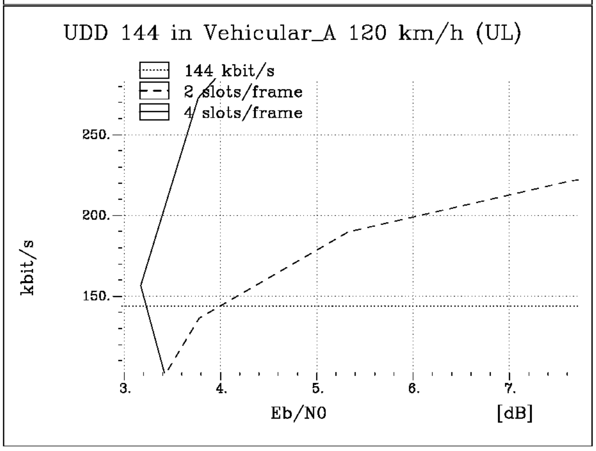


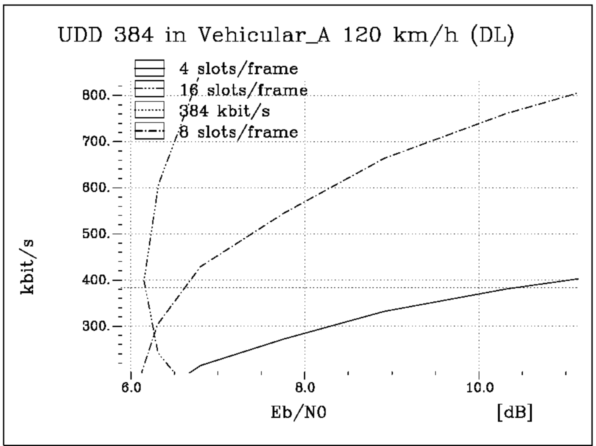



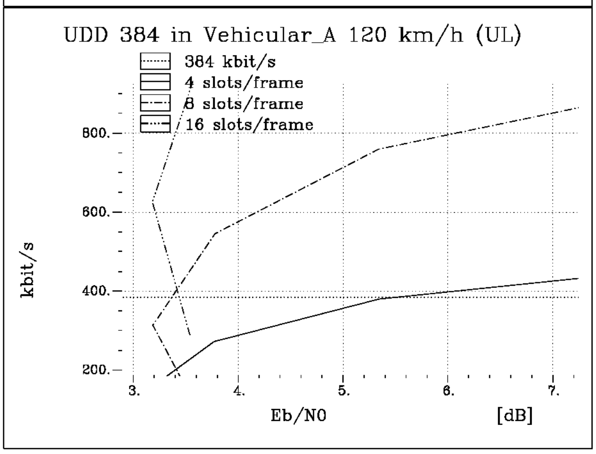

### *7.5.3.3 UDD in ITU Vehicular_A*

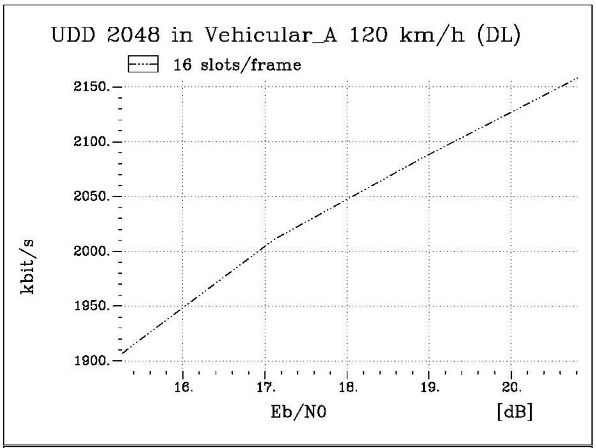
| Parameters | Value(s) |
|---|---|
| Slot size | 1/16 |
| Modulation(s) | Bin-O-QAM |
| Number of slots used per frame | 2, 4, 8, 16 |
| Uncoded data block | 2726 |
| Coding rate | Variable |
| Basic code | CC(1,2,9) |
| Interleaving depth | Over 8 bursts |
| Puncturing | Via hybrid-ARQ |
| Frequency hopping | Slot-by-slot |
| Mobile speed | 120 km/h |
| Antenna diversity | UL: Yes, DL: No |

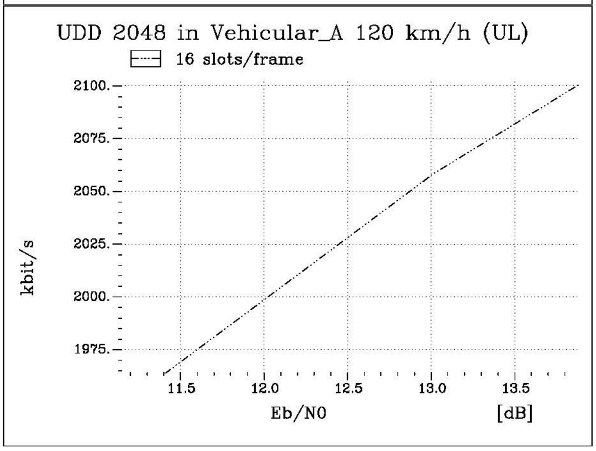

UDD 144 in Vehicular_A 120 km/h (DL)
144 kbit/s
2 slots/frame
4 slots/frame
kbit/s
250.
200.
150.
6.
7.
8.
9.
10.
Eb/N0
[dB]


UDD 144 in Vehicular_A 120 km/h (UL)
144 kbit/s
2 slots/frame
4 slots/frame
kbit/s
250.
200.
150.
3.
4.
5.
6.
7.
Eb/N0
[dB]


UDD 384 in Vehicular_A 120 km/h (DL)
4 slots/frame
16 slots/frame
384 kbit/s
8 slots/frame
kbit/s
800.
700.
600.
500.
400.
300.
6.0
8.0
10.0
Eb/N0
[dB]

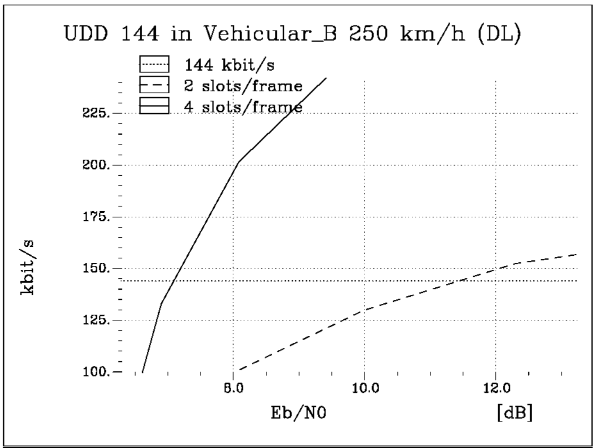

UDD 384 in Vehicular_A 120 km/h (UL)
384 kbit/s
4 slots/frame
8 slots/frame
16 slots/frame
kbit/s
800.
600.
400.
200.
3.
4.
5.
6.
7.
Eb/N0
[dB]

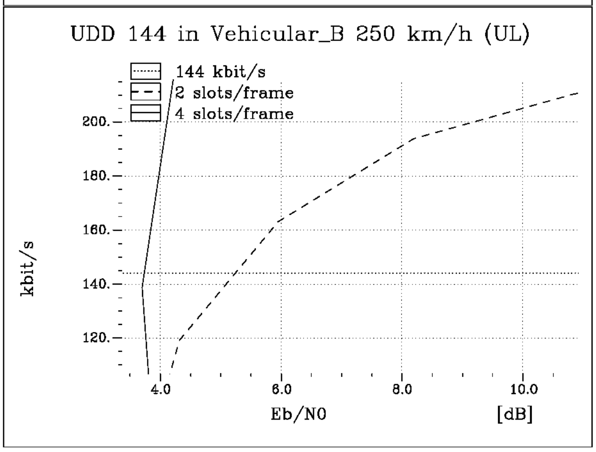


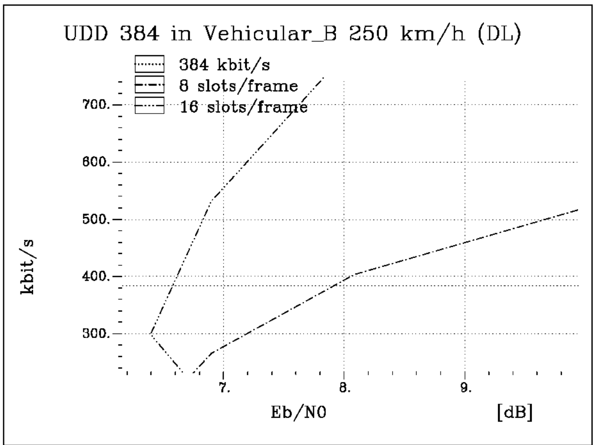



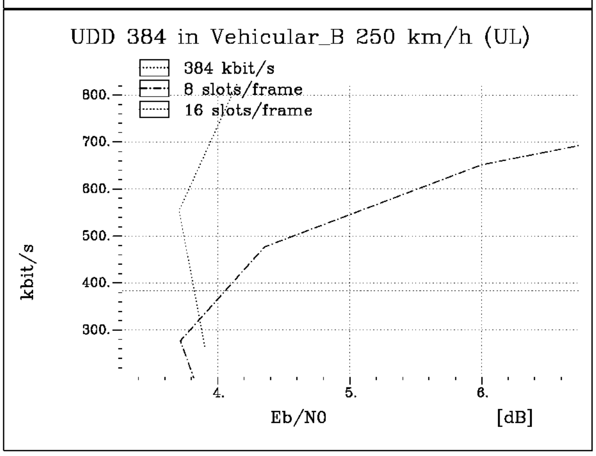

### *7.5.3.4 UDD in ITU Vehicular_B*

| **Parameters** | **Value(s)** |
|---|---|
| Slot size | 1/16 |
| Modulation(s) | Bin-O-QAM |
| Number of slots used per frame | 2, 4, 8, 16 |
| Uncoded data block | 2726 |
| Coding rate | Variable |
| Basic code | CC(1,2,9) |
| Interleaving depth | Over 8 bursts |
| Puncturing | Via hybrid-ARQ |
| Frequency hopping | Slot-by-slot |
| Mobile speed | 250 km/h |
| Antenna diversity | UL: Yes, DL: No |


UDD 144 in Vehicular_B 250 km/h (DL)
144 kbit/s
2 slots/frame
4 slots/frame
225.
200.
175.
150.
125.
100.
kbit/s
8.0
10.0
12.0
Eb/N0
[dB]


UDD 144 in Vehicular_B 250 km/h (UL)
144 kbit/s
2 slots/frame
4 slots/frame
200.
180.
160.
140.
120.
kbit/s
4.0
6.0
8.0
10.0
Eb/N0
[dB]


UDD 384 in Vehicular_B 250 km/h (DL)
384 kbit/s
8 slots/frame
16 slots/frame
700.
600.
500.
400.
300.
kbit/s
7.
8.
9.
Eb/N0
[dB]

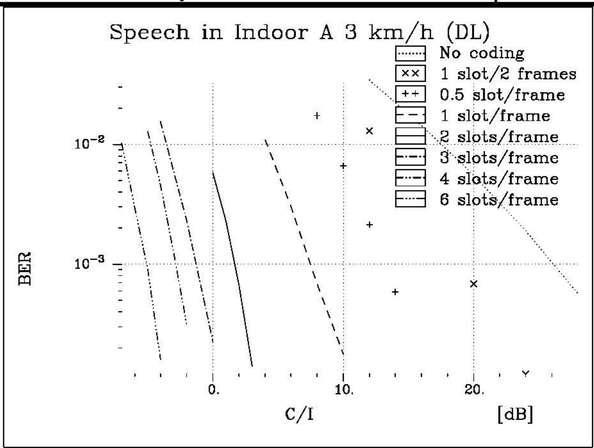

UDD 384 in Vehicular_B 250 km/h (UL)
384 kbit/s
8 slots/frame
16 slots/frame
800.
700.
600.
500.
400.
300.
kbit/s
4.
5.
6.
Eb/N0
[dB]

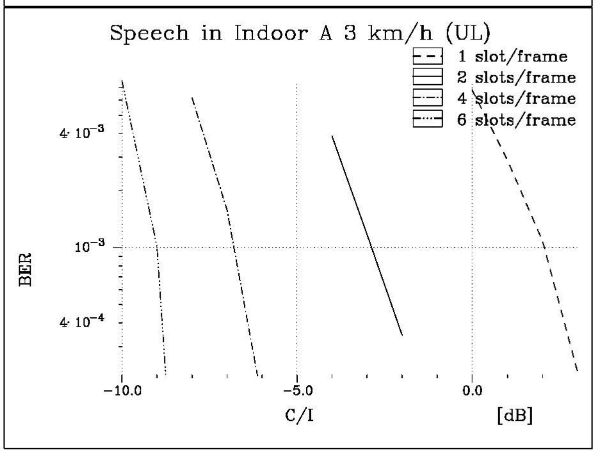
## *7.6 C/I simulation results*

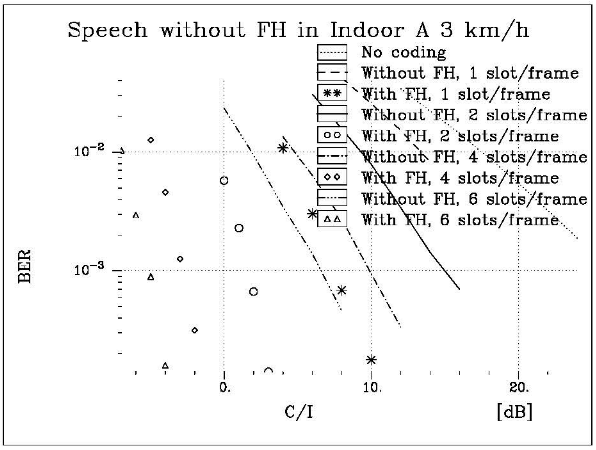
### 7.6.1 Speech

#### *7.6.1.1 Speech in ITU Indoor_A*

| Parameters | Value(s) |
|---|---|
| Slot size | 1/64 |
| Modulation(s) | Bin-O-QAM |
| Number of slots used per frame | 1, 2, 4, 6 |
| Uncoded data block | 150 |
| Coding rate | 0.26, 0.13, 0.07, 0.05 |
| Basic code | CC(1,2,9) |
| Interleaving depth | Over 4 frames |
| Puncturing | Yes |
| Frequency hopping | Slot-by-slot |
| Mobile speed | 3 km/h |
| Antenna diversity | UL: Yes, DL: No |

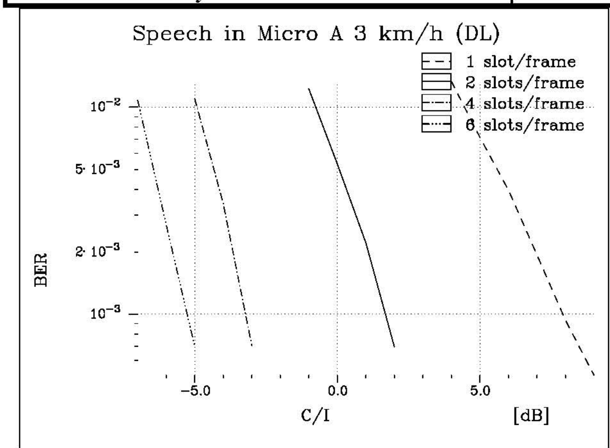


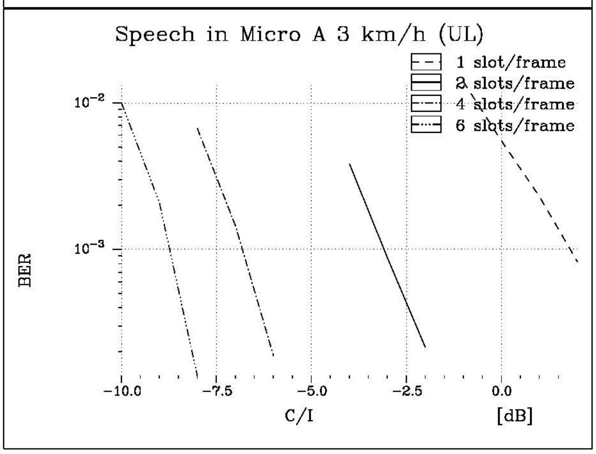






### 7.6.1.2 Speech in ITU Micro_A

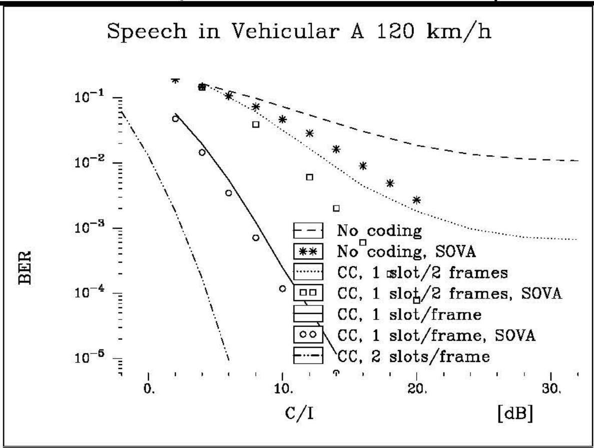
| Parameters | Value(s) |
|---|---|
| Slot size | 1/64 |
| Modulation(s) | Bin-O-QAM |
| Number of slots used per frame | 1, 2, 4, 6 |
| Uncoded data block | 150 |
| Coding rate | 0.26, 0.13, 0.07, 0.05 |
| Basic code | CC(1,2,9) |
| Interleaving depth | Over 4 frames |
| Puncturing | Yes |
| Frequency hopping | Slot-by-slot |
| Mobile speed | 3 km/h |
| Antenna diversity | UL: Yes, DL: No |

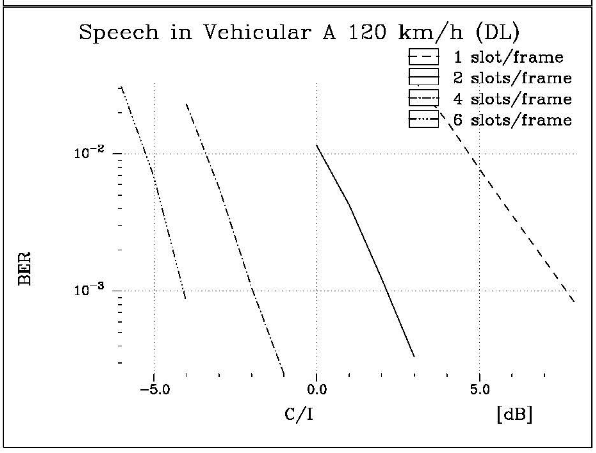


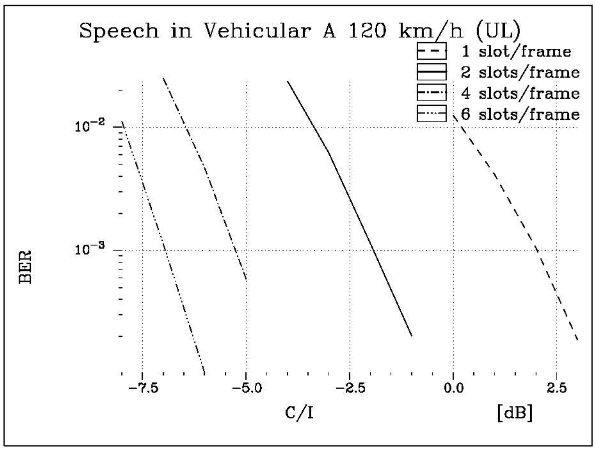



### *7.6.1.3 Speech in ITU Vehicular_A*

| Parameters | Value(s) |
|---|---|
| Slot size | 1/64 |
| Modulation(s) | Bin-O-QAM |
| Number of slots used per frame | 1, 2, 3, 4, 6 |
| Uncoded data block | 150 |
| Coding rate | 0.26, 0.13, 0.09, 0.07, 0.05 |
| Basic code | CC(1,2,5), CC(1,2,9) |
| Interleaving depth | Over 4 frames |
| Puncturing | Yes |
| Frequency hopping | Slot-by-slot |
| Mobile speed | 120 km/h |
| Antenna diversity | UL: Yes, DL: No |

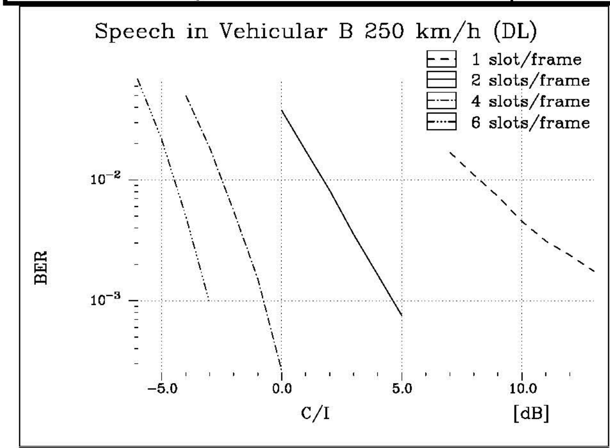


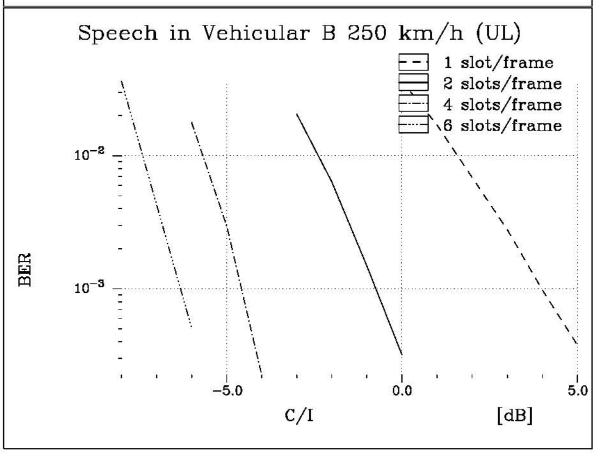



### *7.6.1.4 Speech in ITU Vehicular_B*

| Parameters | Value(s) |
|---|---|
| Slot size | 1/64 |
| Modulation(s) | Bin-O-QAM |
| Number of slots used per frame | 1, 2, 4, 6 |
| Uncoded data block | 150 |
| Coding rate | 0.26, 0.13, 0.07, 0.05 |
| Basic code | CC(1,2,9) |
| Interleaving depth | Over 4 frames |
| Puncturing | Yes |
| Frequency hopping | Slot-by-slot |
| Mobile speed | 250 km/h |
| Antenna diversity | DL: No, UL: Yes |



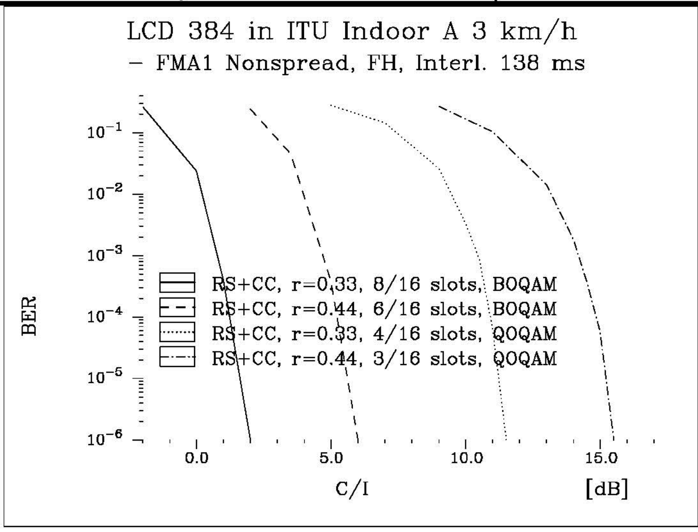




## 7.6.2 LCD

### *7.6.2.1 LCD 384 in ITU Indoor_A*

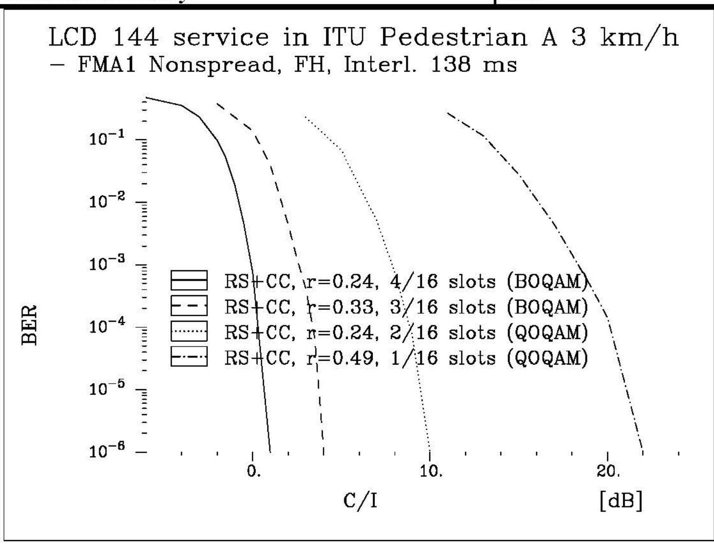
| Parameters | Value(s) |
|---|---|
| Slot size | 1/16 |
| Modulation(s) | Quat-O-QAM, Bin-O-QAM |
| Number of slots used per frame | 3, 4, 6, 8 |
| User bitrate | 390 kbit/s |
| Coding rate | 0.33, 0.44 |
| Basic code | CC(1,2,5), CC(1,3,5), RS-code |
| Interleaving depth | Over 30 frames |
| Puncturing | Yes |
| Frequency hopping | Slot-by-slot |

| | |
|---|---|
| Mobile speed | 3 km/h |
| Antenna diversity | No |




### *7.6.2.2 LCD 144 in ITU Micro_A*

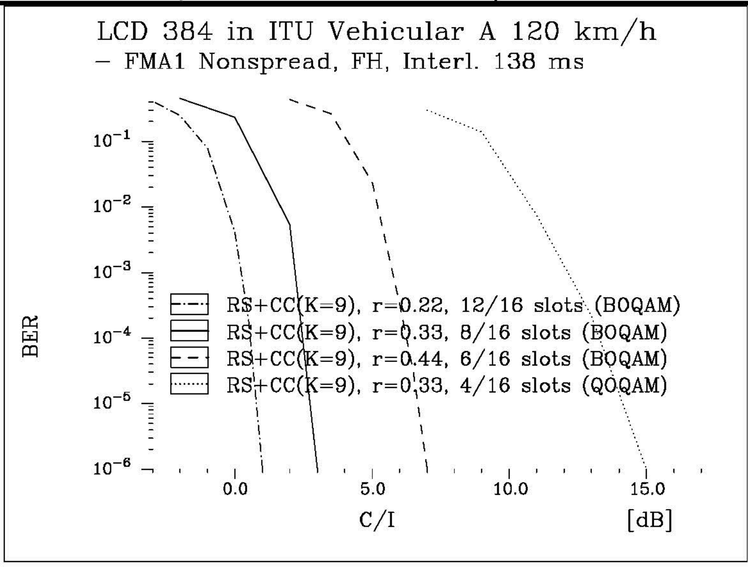
| Parameters | Value(s) |
|---|---|
| Slot size | 1/16 |
| Modulation(s) | Quat-O-QAM, Bin-O-QAM |
| Number of slots used per frame | 1, 2, 3, 4 |
| User bitrate | 145.6 kbit/s |
| Coding rate | 0.24, 0.33, 0.49 |
| Basic code | CC(1,2,5), CC(1,3,5), CC(1,4,5), RS-code |
| Interleaving depth | Over 30 frames |
| Puncturing | Yes |
| Frequency hopping | Slot-by-slot |
| Mobile speed | 3 km/h |
| Antenna diversity | No |




### *7.6.2.3 LCD 384 in ITU Vehicular_A*

| Parameters | Value(s) |
|---|---|
| Slot size | 1/16 |
| Modulation(s) | Quat-O-QAM, Bin-O-QAM |

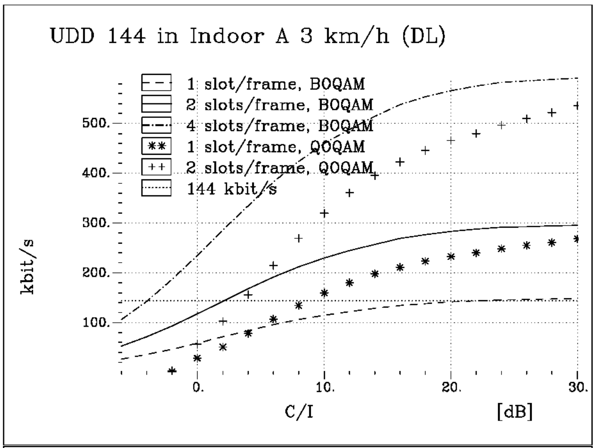
| | |
|---|---|
| Number of slots used per frame | 4, 6, 8, 12 |
| User bitrate | 390 kbit/s |
| Coding rate | 0.22, 0.33, 0.44 |
| Basic code | CC(1,2,5), CC(1,3,5), CC(1,4,5), RS-code |
| Interleaving depth | Over 30 frames |
| Puncturing | Yes |
| Frequency hopping | Slot-by-slot |
| Mobile speed | 120 km/h |
| Antenna diversity | No |

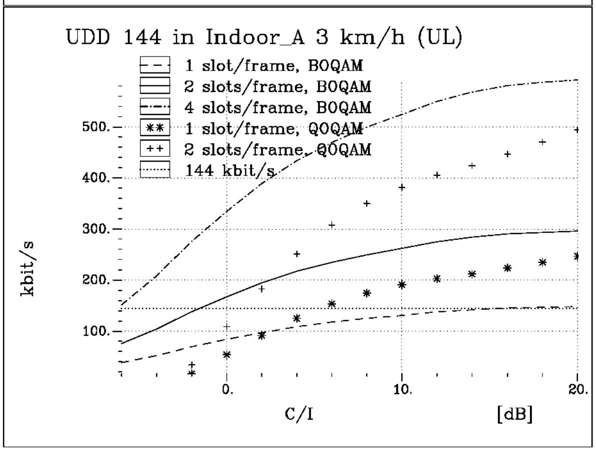


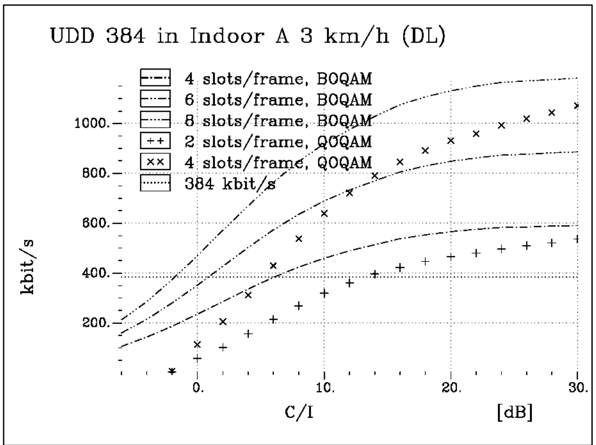

### 7.6.3 UDD

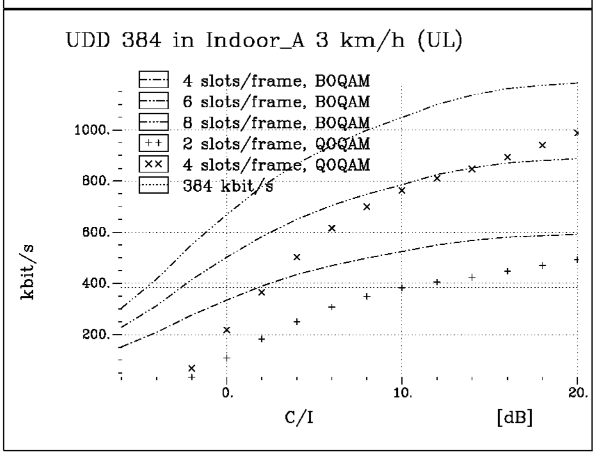
#### *7.6.3.1 UDD in ITU Indoor_A*

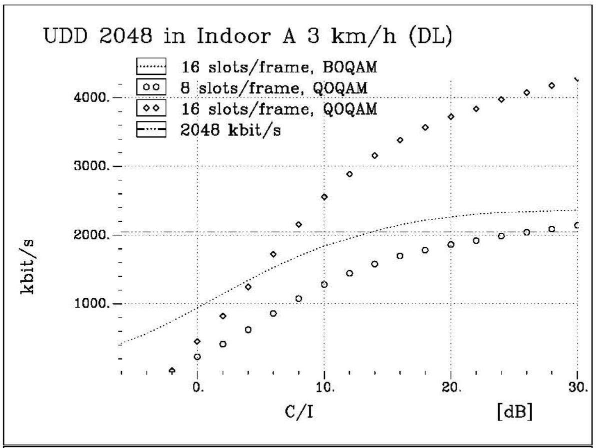
| Parameters | Value(s) |
|---|---|
| Slot size | 1/16 |
| Modulation(s) | Bin-O-QAM and Quat-O-QAM |
| Number of slots used per frame | 1, 2, 4, 6, 8, 16 |
| Uncoded data block | 2726 |
| Coding rate | Variable |
| Basic code | CC(1,2,9) |
| Interleaving depth | Over eigth bursts |
| Puncturing | Via hybrid-ARQ |
| Frequency hopping | Slot-by-slot |
| Mobile speed | 3 km/h |
| Antenna diversity | UL: Yes, DL: No |

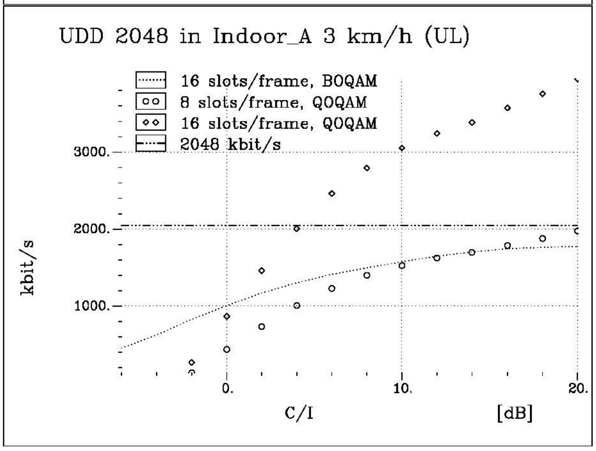

UDD 144 in Indoor A 3 km/h (DL)
1 slot/frame, BOQAM
2 slots/frame, BOQAM
4 slots/frame, BOQAM
1 slot/frame, QOQAM
2 slots/frame, QOQAM
144 kbit/s
kbit/s
100.
200.
300.
400.
500.
0.
10.
20.
30.
C/I
[dB]


UDD 144 in Indoor_A 3 km/h (UL)
1 slot/frame, BOQAM
2 slots/frame, BOQAM
4 slots/frame, BOQAM
1 slot/frame, QOQAM
2 slots/frame, QOQAM
144 kbit/s
kbit/s
100.
200.
300.
400.
500.
0.
10.
20.
C/I
[dB]


UDD 384 in Indoor A 3 km/h (DL)
4 slots/frame, BOQAM
6 slots/frame, BOQAM
8 slots/frame, BOQAM
2 slots/frame, QOQAM
4 slots/frame, QOQAM
384 kbit/s
kbit/s
200.
400.
600.
800.
1000.
0.
10.
20.
30.
C/I
[dB]

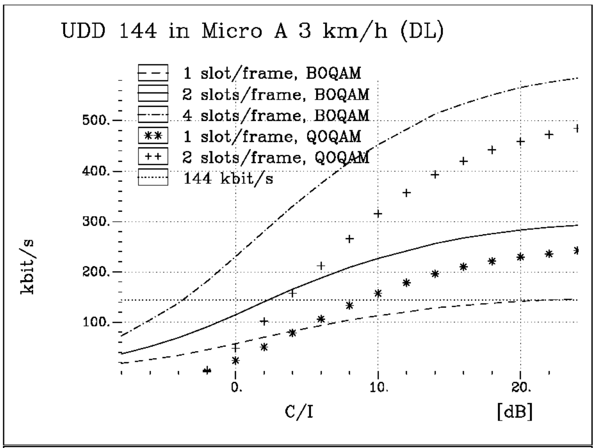

UDD 384 in Indoor_A 3 km/h (UL)
4 slots/frame, BOQAM
6 slots/frame, BOQAM
8 slots/frame, BOQAM
2 slots/frame, QOQAM
4 slots/frame, QOQAM
384 kbit/s
kbit/s
200.
400.
600.
800.
1000.
0.
10.
20.
C/I
[dB]

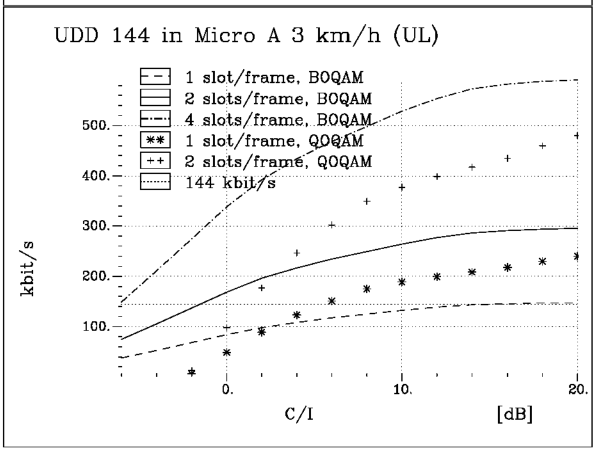


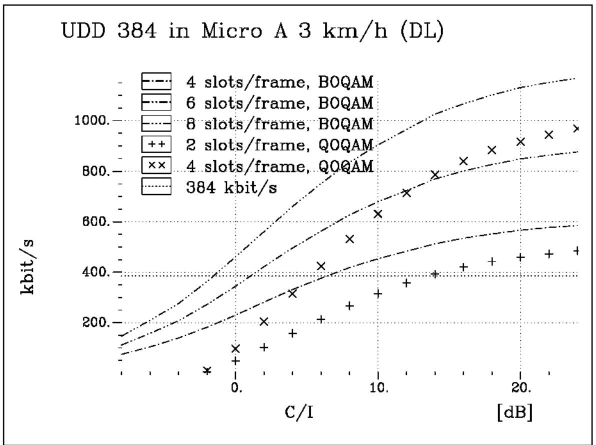



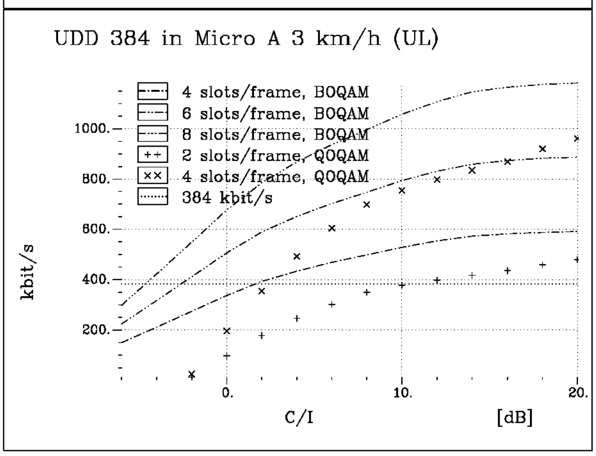

### *7.6.3.2 UDD in ITU Micro_A*

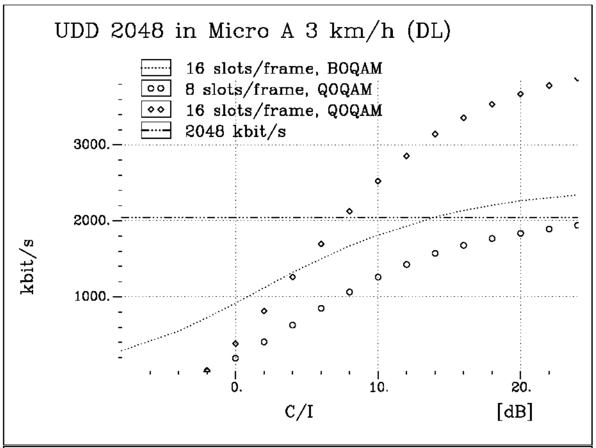
| Parameters | Value(s) |
|---|---|
| Slot size | 1/16 |
| Modulation(s) | Bin-O-QAM and Quat-O-QAM |
| Number of slots used per frame | 1, 2, 4, 6, 8, 16 |
| Uncoded data block | 2726 |
| Coding rate | Variable |
| Basic code | CC(1,2,9) |
| Interleaving depth | Over 8 bursts |
| Puncturing | Via hybrid-ARQ |
| Frequency hopping | Slot-by-slot |
| Mobile speed | 3 km/h |
| Antenna diversity | UL: Yes, DL: No |

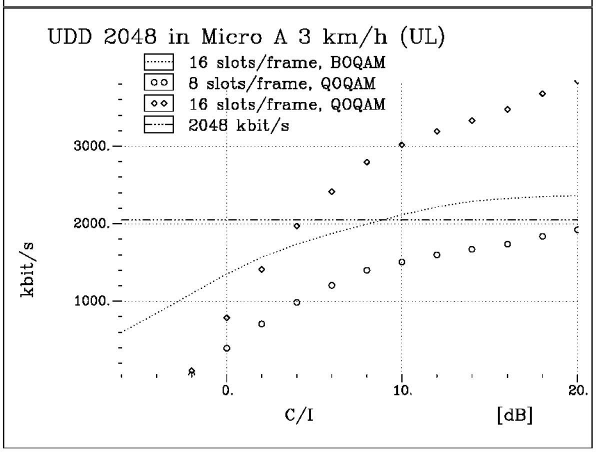

UDD 144 in Micro A 3 km/h (DL)
1 slot/frame, BOQAM
2 slots/frame, BOQAM
4 slots/frame, BOQAM
1 slot/frame, QOQAM
2 slots/frame, QOQAM
144 kbit/s
kbit/s
C/I
[dB]


UDD 144 in Micro A 3 km/h (UL)
1 slot/frame, BOQAM
2 slots/frame, BOQAM
4 slots/frame, BOQAM
1 slot/frame, QOQAM
2 slots/frame, QOQAM
144 kbit/s
kbit/s
C/I
[dB]

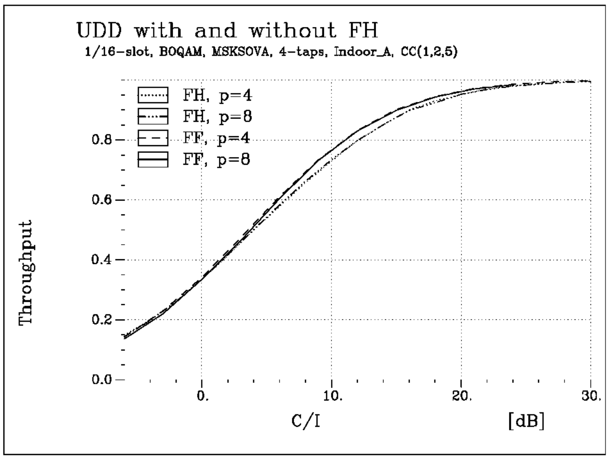

UDD 384 in Micro A 3 km/h (DL)
4 slots/frame, BOQAM
6 slots/frame, BOQAM
8 slots/frame, BOQAM
2 slots/frame, QOQAM
4 slots/frame, QOQAM
384 kbit/s
kbit/s
C/I
[dB]


UDD 384 in Micro A 3 km/h (UL)
4 slots/frame, BOQAM
6 slots/frame, BOQAM
8 slots/frame, BOQAM
2 slots/frame, QOQAM
4 slots/frame, QOQAM
384 kbit/s
kbit/s
C/I
[dB]




Effect of frequency hopping can be illustrated by following simulations. In the sense of the throughput frequency hopping decreases the performance about 0.7 dB.



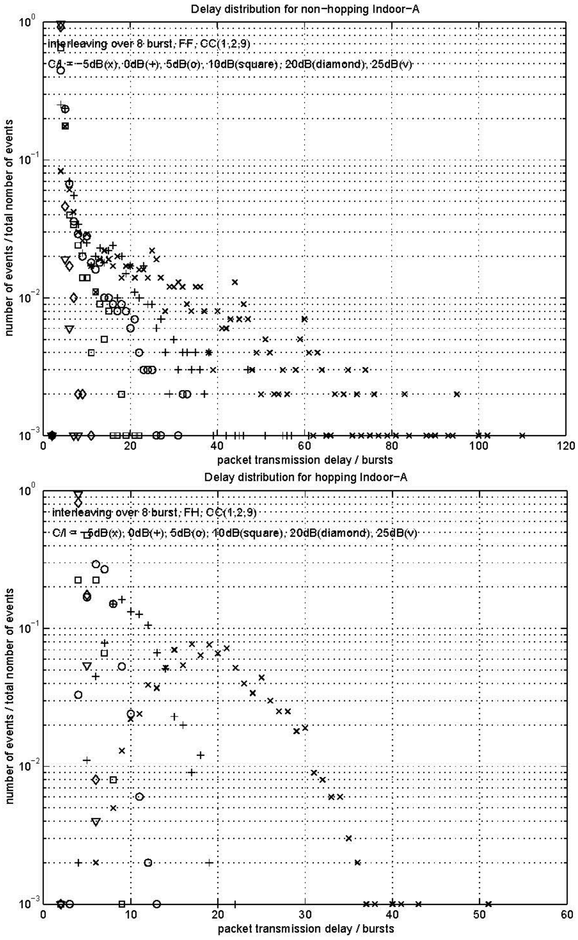

ARQ with (FH) and without (FF) frequency hopping.

However the throughput is not the only measure for packet service quality. It is also beneficial that ARQ-scheme does not produce very high occasional delay. In this sense frequency hopping improves the performance and it also helps to average the interference caused to other users.

Without frequency hopping there occasionally are longer delays for individual packets. However, because the average delays in these two cases are about the same, there are also low delays in the non-hopping case.

In indoor_A channel delays over 10 bursts (~46 ms) were not present if C/I was over 10 dB. With C/I = 0 dB the maximum delay is measured to be 20 bursts (less than 100 ms). Without frequency hopping maximum delays at C/I of 10 dB can exceed 20 bursts and with C/I = 0 dB maximum delays can exceed

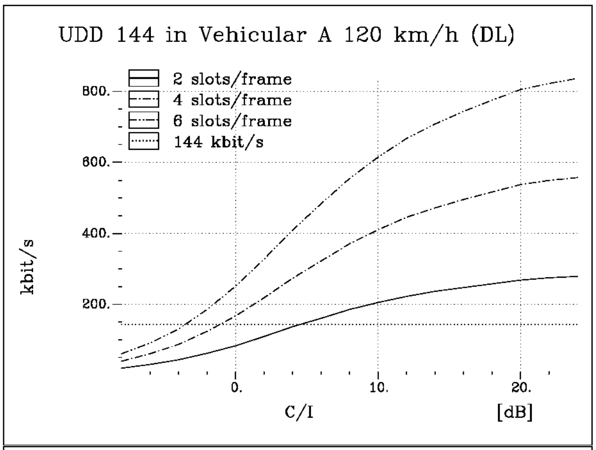
60 bursts (~ 280 ms). In the non-hopping case the delay distribution has longer tail than in the hopping case.

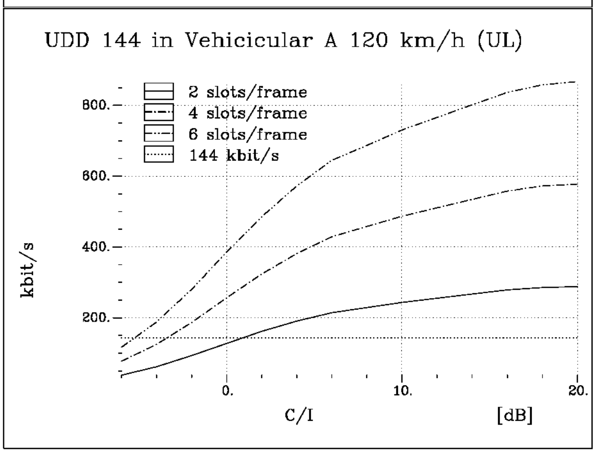


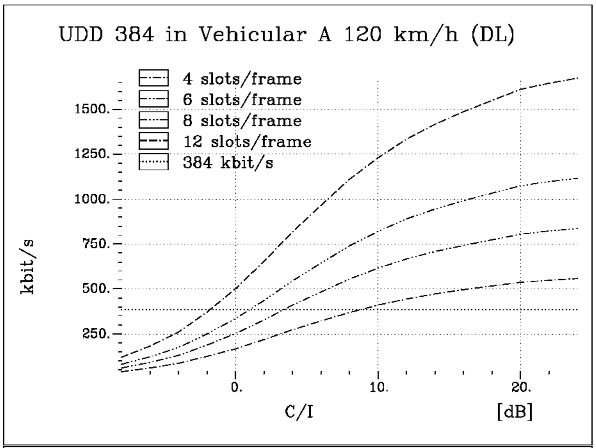

Delay distribution for non-hopping and hopping UDD

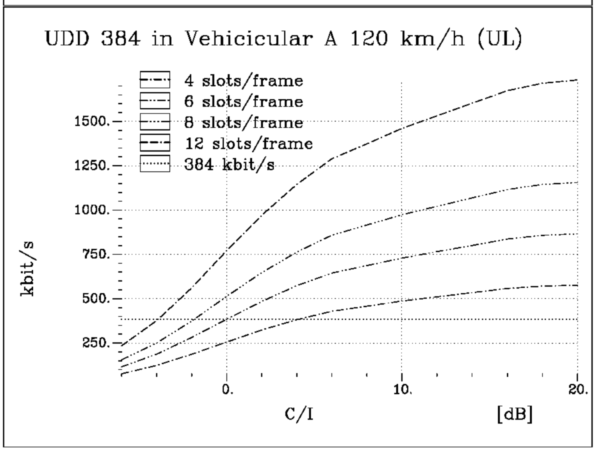
### *7.6.3.3 UDD in ITU Vehicular_A*

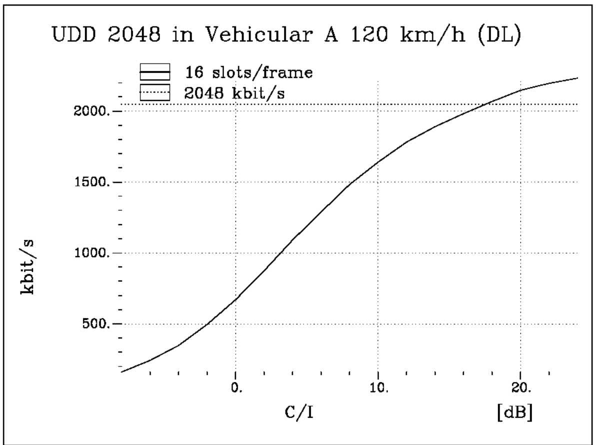
| Parameters | Value(s) |
|---|---|
| Slot size | 1/16 |
| Modulation(s) | Bin-O-QAM and Quat-O-QAM |
| Number of slots used per frame | 2, 4, 6, 8, 12, 16 |
| Uncoded data block | 2726 |
| Coding rate | Variable |
| Basic code | CC(1,2,9) |
| Interleaving depth | Over 8 bursts |
| Puncturing | Via hybrid-ARQ |
| Frequency hopping | Slot-by-slot |
| Mobile speed | 120 km/h |
| Antenna diversity | UL: Yes, DL: No |

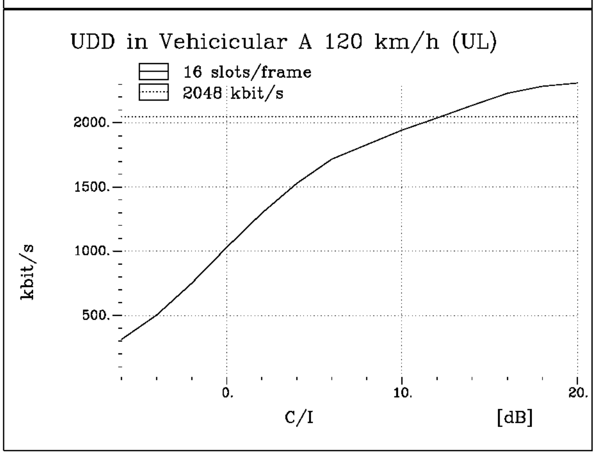

UDD 144 in Vehicular A 120 km/h (DL)
2 slots/frame
4 slots/frame
6 slots/frame
144 kbit/s
kbit/s
800.
600.
400.
200.
0.
10.
20.
C/I
[dB]


UDD 144 in Vehicicular A 120 km/h (UL)
2 slots/frame
4 slots/frame
6 slots/frame
144 kbit/s
kbit/s
800.
600.
400.
200.
0.
10.
20.
C/I
[dB]


UDD 384 in Vehicular A 120 km/h (DL)
4 slots/frame
6 slots/frame
8 slots/frame
12 slots/frame
384 kbit/s
1500.
1250.
1000.
750.
500.
250.
kbit/s
0.
10.
20.
C/I
[dB]

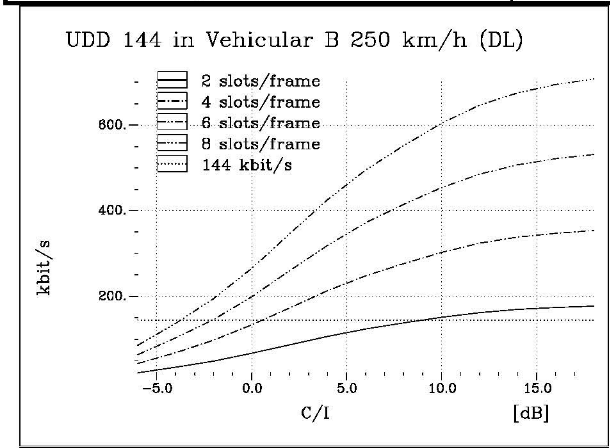

UDD 384 in Vehicicular A 120 km/h (UL)
4 slots/frame
6 slots/frame
8 slots/frame
12 slots/frame
384 kbit/s
1500.
1250.
1000.
750.
500.
250.
kbit/s
0.
10.
20.
C/I
[dB]

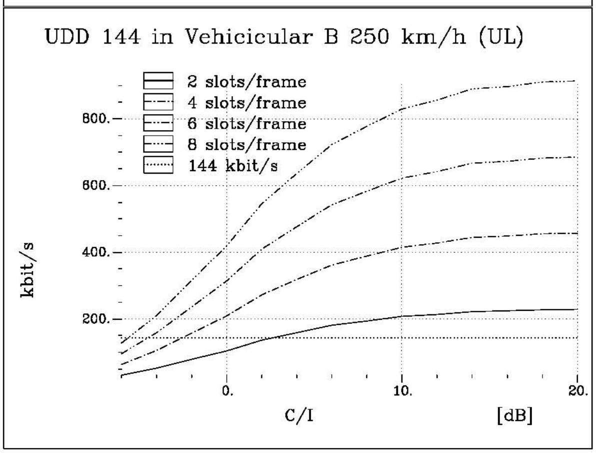

UDD 2048 in Vehicular A 120 km/h (DL)
16 slots/frame
2048 kbit/s
2000.
1500.
1000.
500.
kbit/s
0.
10.
20.
C/I
[dB]

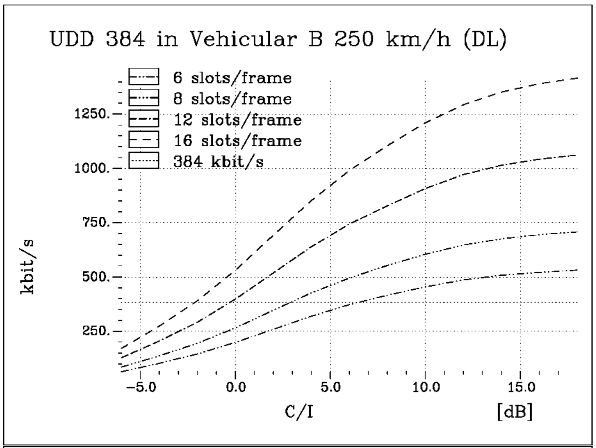

UDD in Vehicicular A 120 km/h (UL)
16 slots/frame
2048 kbit/s
2000.
1500.
1000.
500.
kbit/s
0.
10.
20.
C/I
[dB]

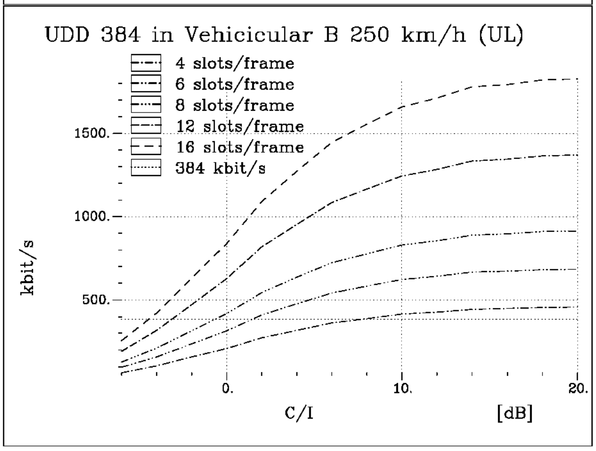
### *7.6.3.4 UDD in ITU Vehicular_B*

| Parameters | Value(s) |
|---|---|
| Slot size | 1/16 |
| Modulation(s) | Bin-O-QAM and Quat-O-QAM |
| Number of slots used per frame | 2, 4, 6, 8, 12, 16 |
| Uncoded data block | 2726 |
| Coding rate | Variable |
| Basic code | CC(1,2,9) |
| Interleaving depth | Over 8 bursts |
| Puncturing | Via hybrid-ARQ |
| Frequency hopping | Slot-by-slot |
| Mobile speed | 250 km/h |
| Antenna diversity | UL: Yes, DL: No |






## 7.6.4 Coverage Analysis

The coverage of WB-TDMA is analysed in the table below and compared to the range of GSM900 and GSM1800. This analysis is based on the WB-TDMA link level simulation against Gaussian noise.

*Table 7-2 :. WB-TDMA coverage calculations for speech service*

| WB-TDMA coverage analysis for speech service | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |
| | | WB-TDMA | | WB-TDMA | | WB-TDMA | | GSM1800 | | GSM900 | |
| | | Downlink | Uplink | Downlink | Uplink | Downlink | Uplink | Downlink | Uplink | Downlink | Uplink |
| Test environment | | Indoor | Indoor | Pedestr. | Pedestr. | Vehicular | Vehicular | Vehicular | Vehicular | Vehicular | Vehicular |
| Multipath channel class | | A | A | A | A | A | A | | | | |
| Test service | | Speech | Speech | Speech | Speech | Speech | Speech | Speech | Speech | Speech | Speech |
| Number of slots used / frame | | 6 | 6 | 6 | 6 | 6 | 6 | 1 | 1 | 1 | 1 |
| Total number of slots / frame | | 64 | 64 | 64 | 64 | 64 | 64 | 8 | 8 | 8 | 8 |
| Bit rate | bit/s | 8000,00 | 8000,00 | 8000,00 | 8000,00 | 8000,00 | 8000,00 | 13000,00 | 13000,00 | 13000,00 | 13000,00 |
| Maximum peak power limitation | dBm | | 30,00 | | 30,00 | | 30,00 | | 30,00 | | 33,00 |
| Average TX power per traffic ch. (ETR0402 | dBm | 10,00 | 4,00 | 20,00 | 14,00 | 30,00 | 24,00 | 30,00 | 24,00 | 30,00 | 24,00 |
| Maximum TX power per traffic ch. | dBm | 20,28 | 14,28 | 30,28 | 24,28 | 40,28 | 30,00 | 39,03 | 30,00 | 39,03 | 33,00 |
| Average TX power per traffic ch. (real) | dBm | 10,00 | 4,00 | 20,00 | 14,00 | 30,00 | 19,72 | 30,00 | 20,97 | 30,00 | 23,97 |
| Maximum total TX power | dBm | 20,28 | 14,28 | 30,28 | 24,28 | 40,28 | 30,00 | 39,03 | 30,00 | 39,03 | 33,00 |
| Cable, conn. and combiner losses | dB | 2,00 | 0,00 | 2,00 | 0,00 | 2,00 | 0,00 | 2,00 | 0,00 | 2,00 | 0,00 |
| TX antenna gain | dBi | 2,00 | 0,00 | 10,00 | 0,00 | 13,00 | 0,00 | 13,00 | 0,00 | 13,00 | 0,00 |
| TX EIRP per traffic channel | dBm | 20,28 | 14,28 | 38,28 | 24,28 | 51,28 | 30,00 | 50,03 | 30,00 | 50,03 | 33,00 |
| Total TX EIRP | dBm | 20,28 | 14,28 | 38,28 | 24,28 | 51,28 | 30,00 | 50,03 | 30,00 | 50,03 | 33,00 |
| RX antenna gain | dBi | 0,00 | 2,00 | 0,00 | 10,00 | 0,00 | 13,00 | 0,00 | 13,00 | 0,00 | 13,00 |
| Cable and connector losses | dB | 0,00 | 2,00 | 0,00 | 2,00 | 0,00 | 2,00 | 0,00 | 2,00 | 0,00 | 2,00 |
| Receiver noise figure | dB | 5,00 | 5,00 | 5,00 | 5,00 | 5,00 | 5,00 | 5,00 | 5,00 | 5,00 | 5,00 |
| Thermal noise density | dBm/Hz | -174,00 | -174,00 | -174,00 | -174,00 | -174,00 | -174,00 | -174,00 | -174,00 | -174,00 | -174,00 |
| RX interference density | dBm/Hz | -1000,00 | -1000,00 | -1000,00 | -1000,00 | -1000,00 | -1000,00 | -1000,00 | -1000,00 | -1000,00 | -1000,00 |
| Total effect. noise + interf. density | dBm/Hz | -169,00 | -169,00 | -169,00 | -169,00 | -169,00 | -169,00 | -169,00 | -169,00 | -169,00 | -169,00 |
| Information rate (during tx) | dBHz | 49,31 | 49,31 | 49,31 | 49,31 | 49,31 | 49,31 | 50,17 | 50,17 | 50,17 | 50,17 |
| Required Eb/(No+Io) | dB | 8,40 | 5,90 | 8,60 | 5,90 | 8,70 | 6,60 | 12,00 | 12,00 | 12,00 | 12,00 |
| RX sensitivity | dB | -111,29 | -113,79 | -111,09 | -113,79 | -110,99 | -113,09 | -106,83 | -106,83 | -106,83 | -106,83 |
| Handoff gain | dB | 4,10 | 4,10 | 3,00 | 3,00 | 3,00 | 3,00 | 3,00 | 3,00 | 3,00 | 3,00 |
| Explicit diversity gain | dB | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 4,50 | 0,00 | 4,50 |
| Other gain | dB | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 | 0,00 |
| Log-normal fade margin | dB | 15,40 | 15,40 | 11,30 | 11,30 | 11,30 | 11,30 | 11,30 | 11,30 | 11,30 | 11,30 |
| Maximum path loss | dB | 120,27 | 116,77 | 141,07 | 137,77 | 153,97 | 145,79 | 148,56 | 144,03 | 148,56 | 147,03 |
| Maximum range | m | 596,54 | 456,01 | 669,85 | 553,96 | 4875,37 | 2954,25 | 3500,77 | 2652,54 | 5374,45 | 4893,49 |

The maximum range of WB-TDMA for speech service is longer than the range of GSM1800 speech service.

It should be noticed that the coverage analysis for speech service is based on 6 slot transmission. Those other 58 slots in a TDMA frame in that carrier can be used to support other users and this does not affect the range of the 6-slot user. For example, if other users take 1 slot/frame on average, 58 other users can be supported with one 1.6 MHz carrier while still providing the maximum range for one user. If this WB-TDMA scheme is compared to other proposals with e.g. 5 MHz bandwidth, then total of 3 WB-TDMA carriers can be used at the same bandwidth to support even a higher number of users while providing the maximum range. This implies that the intra-cell interference does not reduce the coverage area of WB-TDMA and the coverage of cellular WB-TDMA network is fairly insensitive to the traffic load.

It should also be noticed that the average transmission power in Vehicular environment is 4.3 dB lower that the maximum average power given in ETR0402. This is due to the limitation set on the MS peak power. The lower average power also implies lower power consumption of the mobile station power amplifier at the cell edge.

The handoff gain in the table above is an estimated figure which should be verified by simulations. The current assumption is that the hard handoff gain is 2.0 dB lower than the soft handoff gain in the alpha group assumptions. In case of a single cell the handoff gain would be 0.0 dB in both concept groups.

## 7.6.5 Discussion

These simulations have been done with FDD assumption. To some extent these results can be generalised to show the performance for TDD mode. Detailed TDD simulations would be needed to evaluate the TDD specific features such as flexibility for resource allocation in up- and downlink and utilisation of asymmetric spectrum allocations.

## 7.6.6 References

[1] ETSI SMG2 UMTS ad hoc #3 TDoc 73, Rennes, 1997.

[2] ETR0402 “Selection procedure for the choice of radio technologies of UMTS”

## *7.7 System Level Simulations*

### 7.7.1 Introduction

This chapter describes the executed system level simulations and the assumptions used in them. The simulated system is WB-TDMA utilizing the Interference Averaging (IA) concept. The main features of the IA-concept are frequency hopping on the whole operator bandwidth, time hopping, link adaptation, type II hybrid ARQ and quality based Handover (HO). Frequency Hopping (FH) and Time Hopping (TH) provide interference averaging and Link Adaptation (LA) provides interference diversity which are the cornerstones of the scheme.

### 7.7.2 Basic assumptions

Only the *downlink* direction is considered. It is expected that downlink will be the capacity limiting direction. Advanced receiver techniques such as antenna diversity can be used in the uplink to make its capacity exceed that of the downlink. Additionally, the locations of the interfering transmitters (mobile stations) will also change providing more interference diversity gain through FH and TH in the uplink. Hence the lower limit for performance is presented.

In the following the major assumptions that have effect on the performance are presented.

#### *7.7.2.1 General models*

All test environments, propagation models, mobility models and quality of service (QoS) criteria for Real Time (RT) and Non real time users are modeled according to [1]. In addition if a user receives all requested bits within 150 ms the user is regarded as a satisfied user.

#### *7.7.2.2 Channel allocation*

Channels are allocated frame by frame independently in each BTS. RT services are prioritized over NRT services. Channel allocation for RT services is based on 'first come first served' principle. Within NRT services users having difficulties to maintain the minimum bit rate and NRT users with lowest transmitted power per slot are prioritized over the rest of the NRT users.

For channel allocation, a channel matrix for each BTS is defined. It contains $f \times t$ slots, where $f$ is the amount of frequencies available for the BTS and $t$ is the amount of slots in one FMA1 frame. A channel separation of 1.6 MHz is used, thus the maximum size for the channel matrix is nine frequencies and 64 or 16 time slots for 1/64 and 1/16 slots structures respectively. However, to speed up simulations with some simulation cases less frequencies and/or time slots have been used. The amount of used frequencies and time slots in each simulation case are indicated together with the simulation results. Use of less frequencies and time slots (smaller channel matrix) in the simulation than the maximum number available on the band causes less diversity and more blocking, thus this is a pessimistic assumption and worse performance is obtained.

#### *7.7.2.3 Frequency and time hopping*

Random uncorrelated memoryless frequency hopping is applied. The random hopping introduces interference diversity, uncorrelated means that the channel fading of different frequencies are uncorrelated, memoryless means that each frequency has the same probability to be chosen regardless of the previously used frequencies. As an example; if nine frequencies are used in a BTS, there is 1/9 probability that two consecutive slots of one particular connection use same frequency. For time hopping there are no restrictions which time slots a terminal can use. User carrier and interfering carrier are slot synchronized but this is not utilized in the simulations, e.g. by joint detection.

#### *7.7.2.4 Power control*

Slow pathloss based power control is applied. The dynamic range of the power control is 30 dB or less. The dynamic range for each simulation case is given in chapter 3.

#### *7.7.2.5 Handover*

Simple pathloss based handover with hand over margin of 3 dB is used, i.e., handover is performed to a new base station if the pathloss to the new base station is 3 dB lower than to the serving base station. In indoor simulations, HO to a BTS in a different floor is prohibited. Taking into account very high standard deviation (12 dB) for indoor slow fading, this probably has a negative effect to the capacity.

#### *7.7.2.6 Link Adaptation*

For RT users quality based link adaptation is used. The channel coding rate is increased when the connection experiences a bad frame and if the serving BTS has extra radio resources available. Amount of channel coding will be decreased if less channel coding would have continuously been sufficient for certain amount of frames. If needed, LA can be done at the beginning of an interleaving period.

For NRT the link adaptation is performed with type II hybrid ARQ, thus the coding rate depends on the amount of retransmissions. The modulation is kept constant over the whole simulation.

#### *7.7.2.7 Type II hybrid ARQ*

In the used ARQ scheme user data is coded with ½-rate convolution code and interleaved over 4 bursts. The interleaving is done in a such way that decoding is possible after two of four bursts have been received. Thus the effective coding rate is one. If the decoding is not successful third burst is sent and decoding is redone. After third burst the coding rate is 2/3. If the decoding is still not successful fourth burst is sent and decoding is done again, now with the coding rate of ½. If the decoding is still not successful, the burst with the lowest C/(I+N) value is resent and the original burst and the retransmitted burst are combined by adding their C/(I+N) values (maximal ratio combining). This repetition coding is repeated until the decoding is successful.

#### *7.7.2.8 DTX*

Radio resources of speech user are released during the DTX period. If there are no resources available after the DTX period bit error rate of 0.5 is applied until resources are allocated or the user is dropped.

#### *7.7.2.9 Modulation adaptation*

Simple modulation adaptation algorithm is used for UDD services. Preferred modulation is Q-O-QAM but B-O-QAM is used for small packets.

#### *7.7.2.10 Frequency Planning*

A characteristic feature of the simulated IA concept is very simple frequency planning with frequency re-use 1. Thus all the frequencies can be used at each base station. Through fractional loading the load in each cell is always less than 100%. Due to fixed antenna pattern in [1], reuse 1/3 is used in vehicular environment (macro).

#### *7.7.2.11 Interface between system and link level simulation*

Link level simulation and system level simulations are connected to each other by using the actual value interface [2]. The actual value interface makes it possible to simulate fast radio resource algorithms on the system level. The actual value interface also increases the simulation realism considerably.

The actual value interface is a novel way to connect link and system level simulations. In the actual value approach the link level simulation data e.g. bit errors are measured for every burst or frame. This means however, that possible de-interleaving and decoding has to be considered on the system level. The performance of receiver algorithms, such as decoding, are not measured or analyzed in the system level simulations, but their performance is considered on the link level. The effect of receiver algorithms is seen in the link level results that are given as inputs to the system level simulation.

If the system level simulation is done with an actual value interface, fast fading has to be taken into account in addition to slow fading and pathloss. With the average value interface fast fading was neglected, since the input from the link level and correspondingly the channel was averaged over a long period (and the fast fading characteristics were included on the link level). With the actual value interface, non-averaged link level simulations are used. Thus fast fading has to be considered on the system level. The same kind of correlated fading process is used both in link- and system level simulations, modeled as Rayleigh, with a certain Doppler frequency.

The strength of an actual value interface, compared to the average value interface, is that all the radio resource management algorithms can be simulated on the system level accurately since the simulation resolution is as accurate as the resolution of the mentioned algorithms. The actual value interface enables possible gain or loss of frequency hopping, ARQ and link adaptation algorithms. If frequency hopping was simulated on the link level and the average value interface was used, interference diversity gain could not be modeled. This is because in the link level simulations only interfering user(s) operating with the same frequency as the observed user can be considered. Correspondingly, if ARQ was simulated on the link level, the varying interference conditions that have their impacts to ARQ performance could not be taken into account. Link adaptation can be simulated thoroughly only on the system level since adaptation decisions depend only on the changing interference conditions. If the link adaptation algorithm was fast the average value interface could not be used.

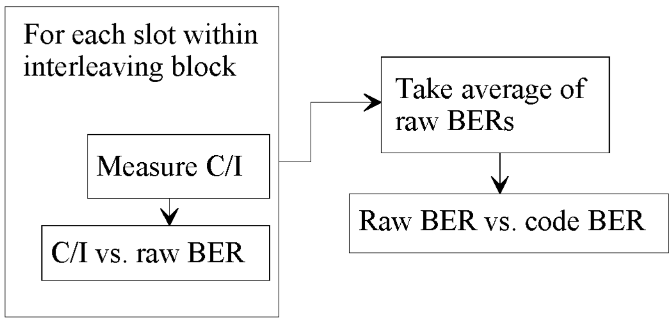



*Figure 1. Block diagram of interface for RT bearers.*

The selected interface for FMA1 is similar as presented in [3]. In [3], however, no fast fading is used in system level. An actual value interface for GSM is presented in [4] to take into account interference and frequency diversity. The accuracy of this interface has been tested in [4] also with different number of hopping frequencies available.

In the method presented here, link level simulation results are collected on a burst-by-bust basis, i.e. C/I and BER values are collected for each burst and coded BER/FER values for each interleaving period. E.g. if the target service has interleaving over 4 bursts, then C/I values for 4 bursts are observed directly from the fading channel and BER/FER of the coding block is measured over the interleaving period. In the link level simulation raw BER (BER before decoding and de-interleaving) versus C/I ratio is measured for each burst within the interleaving block. In the system level the C/I ratio is measured for each burst within the interleaving block and is mapped to raw BER by using a *raw BER vs. C/I curve* from the link level. De-interleaving is modeled so that the average raw BER within the interleaving block is calculated. Further, decoding is modeled by mapping the de-interleaved raw BER to the coded BER/FER by using the measured *mean raw BER vs. coded BER/FER curve*. The actual value interface for FMA1 is depicted in Figure 1, C/I vs. raw BER curve in Figure 2a and mean raw BER vs. coded BER curve in Figure 2b.

### 7.7.3 Results

Simulation results are collected to Table 1. Detailed description of the simulations carried out are presented in the following chapters.

Table 1. Summary of the system simulations results

| Environment | Service | Capacity [kbps/MHz/cell] | Notes |
|---|---|---|---|
| Outdoor to indoor | UDD384 | 811 | |

| | | | |
|---|---|---|---|
| pedestrian | | | |
| | Speech | 190 | |
| Indoor | UDD2048 | 332 | |
| | Mixed | 60 | *Preliminary result* |
| Indoor'with walls' | UDD2048 | 743 | *Wall attenuation 5 dB* |
| Vehicular | Speech | 55 | |
| | LCD384 | 113 | |

### *7.7.3.1 Micro cell*

#### 7.7.3.1.1 UDD384

The simulated Spectrum efficiency is **811 kbps/MHz/cell**. Of all sessions 99.7% fulfill all quality criteria. Dropping is the major reason for not fulfilling all quality criteria, the bad quality criterion has not any practical effects.

The average active session throughput is 405 kbps and 46 % of the sessions have active session throughput 384 kbps or higher. The respective ratios for 512 kbps, 1Mbps and 2Mbps are 24%, 3.1% and 0.25%. Thus higher bit rate are also possible in outdoor to indoor pedestrian environment. The distribution of active session throughputs can be seen in Figure 1. Reuse 1 is used with fractional load of 79%. In Figure 2 histogram for needed transmissions per a hybrid II ARQ packet is presented.

With micro cell UDD384 simulations the channel matrix is 16 time slots x 5 frequencies due to simulation complexity reasons (9 frequencies could have been used). Thus channel diversity gain and specially the statistical multiplexing gain is reduced. The preferred modulation is Q-O-QAM, but the modulation is switched to B-O-QAM if offer traffic does not require Q-O-QAM. If less bits that can be transmitted in one radio packet are sent, the radio packet is filled with dummy bits. These overhead dummy bits are not included into spectrum efficiency nor into active session throughput. The dynamic range for the power control is 30 dB.

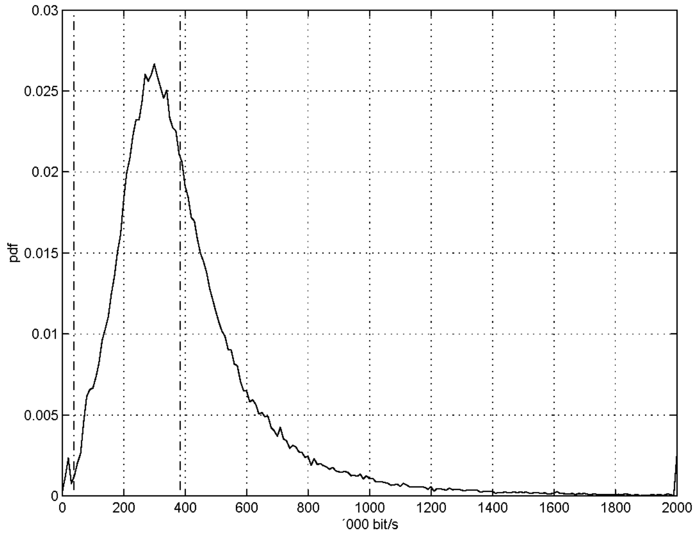



Figure 1. Histogram for session throughputs

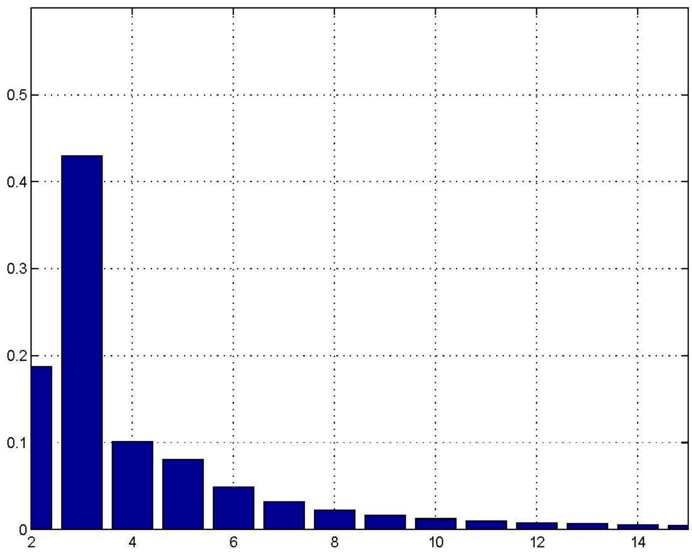



Figure 2. Histogram for needed transmissions per hybrid II ARQ packet. Both Q-O-QAM and B-O-QAM packet are included.

#### 7.7.3.1.2 Speech

The simulated capacity is **190 kbps/MHz/cell**. Then the blocking and dropping are ca. 0 and bad quality is ca. 2 %. Thus quality requirements are fulfilled with that loading. An user uses in average 1.12 slots per frame when it is active. The developed fractional cell loading was 65 % in the six middle cells. The used power dynamics was 30 dB.

With micro cell speech simulations the matrix was 16 time slots x 9 frequencies. In reality the number of time slots would be 64. Only 16 time slots were used in order to reduce simulation time. Thus less diversity is obtained and more blocking happens which leads to that the simulated capacity becomes lower than with the full channel matrix.

### *7.7.3.2 Indoor*

#### 7.7.3.2.1 UDD2048

The simulated spectrum efficiency is **332 kbps/MHz/cell**. Of all sessions 98.4 % fulfill quality criteria. If all bits user requests during a session are received correctly within 150 ms, the user is regarded as satisfied user independent of active bit rate. Insufficient active session throughput is the limiting reason for most sessions not fulfilling the performance criteria.

The average active session throughput is 713 kbps and 0.4 % of the sessions have active session throughput 2048 kbps or higher. If offered load is reduced the average active session throughput and ratio of the users having active session throughput 2048 kbps or higher increases. Reuse 1 is used with fractional load of 48%. The distribution of active session throughputs can be seen in Figure 3. In Figure 4 histogram for needed transmissions per a hybrid II ARQ packet is presented.

With pico cell UDD2048 simulations the channel matrix was 16 time slots x 9 frequencies. The preferred modulation is Q-O-QAM, but the modulation is switched to B-O-QAM if offer traffic does not require Q-O-QAM. If the BTS buffer has less bits that can be transmitted in a one radio packet, the radio packet is filled with dummy bits. These overhead dummy bits are not included into spectrum efficiency nor into active session throughput. The dynamic range of the power control is 30 dB.

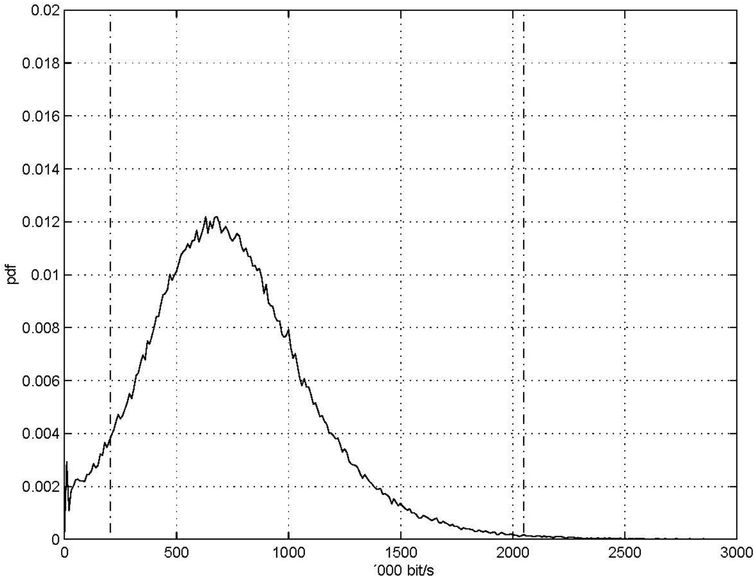



Figure 3. Histogram for session throughputs.

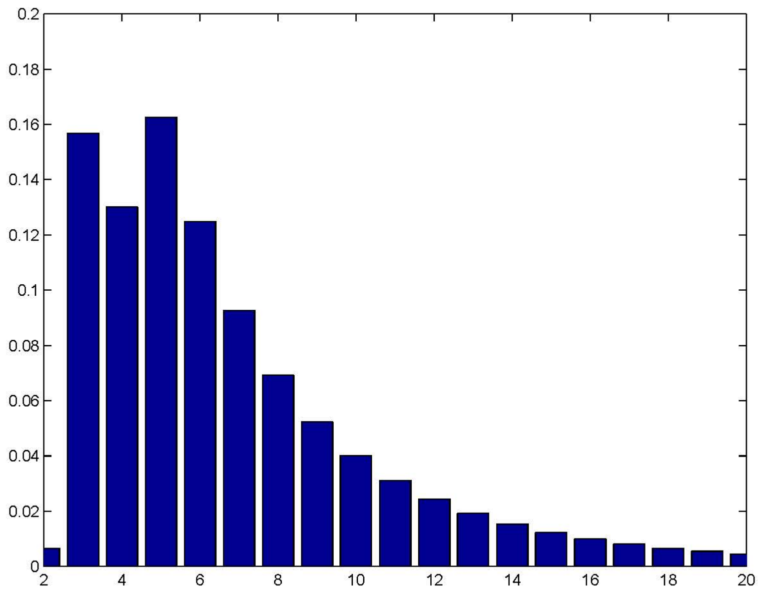


Figure 4. Histogram for needed transmissions per hybrid II ARQ packet. Both Q-O-QAM and B-O-QAM packet are included.

### 7.7.3.2.2 Mixed

The simulated spectrum efficiency is **60 kbps/MHz/cell**. Of all speech user 99 % and 99.8% of all NRT384 sessions fulfill quality criteria. Thus the presented result is *very preliminary* result. With mixed speech and UDD384 simulation channel matrix of 9 frequencies and 16 times slots is used. According to ETSI definitions 50% of the ongoing users are speech users and the other 50 % are UDD384 users. Taking into account that the mean holding time for UDD384 users depends on the network load, the analytical birth processes can not be derived. Instead one birth process is used for both services and the probability of the service of the new user depends on the ratio of speech and UDD384 users.

### 7.7.3.2.3 Indoor with walls

Indoor model defined in [1] has hardly any isolation between cells in same floor. Therefore additional simulations with walls are carried out. UDD2048 simulation with walls is otherwise identical to

UDD2048 simulation without walls presented in this paper, expect it has additional wall attenuation of 5 dB and standard deviation of slow fading is reduced from 12 dB to 4 dB.

The simulated spectrum efficiency is **743 kbps/MHz/cell**. Of all sessions 98.7 % fulfill quality criteria. If all bits user requests during a session are received correctly within 150 ms, the user is regarded as satisfied user independent of active bit rate. Insufficient active session throughput is the limiting reason for most sessions not fulfilling the performance criteria.

The average active session throughput is 692 kbps and 0.4 % of the sessions have active session throughput 2048 kbps or higher. If offered load is reduced the average active session throughput and ratio of the users having active session throughput 2048 kbps or higher increases. Reuse 1 is used with fractional load of 86 %. The distribution of active session throughputs can be seen in Figure 5. In Figure 6 histogram for needed transmissions per a hybrid II ARQ packet is presented.

With pico cell UDD2048 simulations the channel matrix was 16 time slots x 8 frequencies. The preferred modulation is Q-O-QAM, but the modulation is switched to B-O-QAM if offer traffic does not require Q-O-QAM. If the BTS buffer has less bits that can be transmitted in a one radio packet, the radio packet is filled with dummy bits. These overhead dummy bits are not included into spectrum efficiency nor into active session throughput. The dynamic range of the power control is 30 dB.

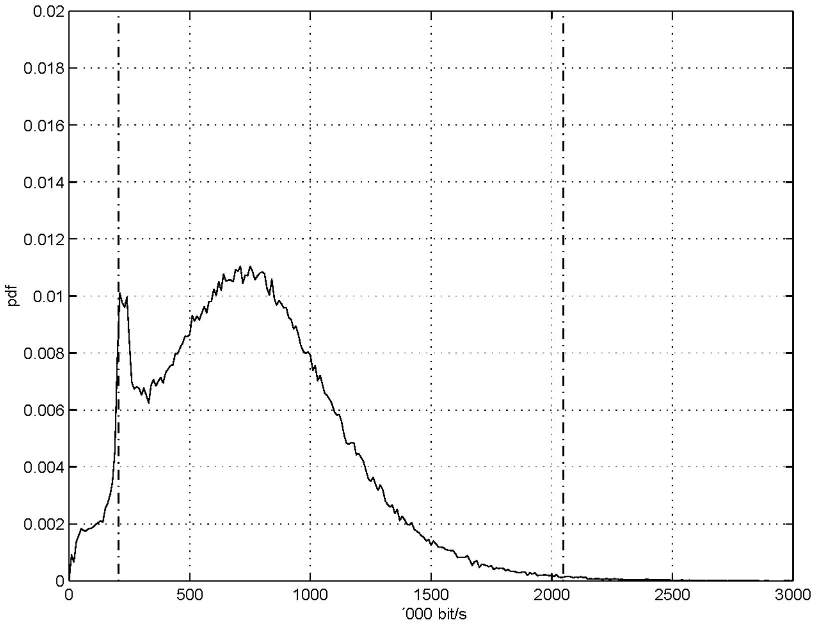



Figure 5. Histogram for session throughputs.