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*Technical Specification*

## Broadband Radio Access Networks (BRAN); HIPERACCESS; PHY protocol specification

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# Foreword

This Technical Specification (TS) has been produced by ETSI Project Broadband Radio Access Networks (BRAN).

The present document describes the physical layer specifications for HIgh PErformance Radio ACCESS network (HIPERACCESS). Separate ETSI documents provide details on the system overview, data link control (DLC) layer, convergence layers (CL) and conformance testing requirements for HIPERACCESS.

# 1 Scope

The present document applies to the HIPERACCESS air interface with the specifications of layer 1 (physical layer), following the ISO-OSI model. HIPERACCESS is confined to only the radio subsystem consisting of the *physical (PHY) layer* and the *DLC layer* - which are both core network independent - and the core network specific *convergence sub-layer*.

For managing radio resources and connection control, the data link control (DLC) protocol is applied, which uses the transmission services of the DLC layer. Convergence layers above the DLC layer handle the inter-working with layers at the top of the radio subsystem.

The scope of the present document is as follows:

- It gives a description of the physical layer for HIPERACCESS system.
- It specifies the transmission scheme in order to allow interoperability between equipment developed by different manufacturers. This is achieved by describing all signal processing structure only in the transmitter side, including scrambling, channel coding, modulation, framing, power control parameters and measurements to support the radio resource management.
- For completeness the specification includes basic RF aspects, including the radio frequency channel plans and those other parameters necessary for radio regulatory purposes. Some of these radio parameters will be repeated in a separate EN to create a harmonized standard within the regulatory framework of the R&TTE Directive (see bibliography).
- Some informative clauses and annexes include parameters and models, which are inputs for preparation of conformance, interoperability and coexistence testing specifications.

The present document does not address the requirements and technical characteristics for conformance testing purposes. These are covered in separate documents.

# 2 References

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

- References are either specific (identified by date of publication and/or edition number or version number) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies.

[1] ETSI EN 301 997-1: "Transmission and Multiplexing (TM); Multipoint equipment; Radio Equipment for use in Multimedia Wireless Systems (MWS) in the frequency band 40,5 GHz to 43,5 GHz; Part 1: General requirements".

[2] ETSI EN 301 213-1: "Fixed Radio Systems; Point-to-multipoint equipment; Point-to-multipoint digital radio systems in frequency bands in the range 24,25 GHz to 29,5 GHz using different access methods; Part 1: Basic parameters".

[3] ETSI EN 301 213-3: "Fixed Radio Systems; Point-to-multipoint equipment; Point-to-multipoint digital radio systems in frequency bands in the range 24,25 GHz to 29,5 GHz using different access methods; Part 3: Time Division Multiple Access (TDMA) methods".

[4] ETSI EN 301 390: "Fixed Radio Systems; Point-to-point and Point-to-Multipoint Systems; Spurious emissions and receiver immunity at equipment/antenna port of Digital Fixed Radio Systems".

[5] CEPT/ERC Recommendation 74-01: "Spurious emissions".

[6] EN 55022: "Information technology equipment - Radio disturbance characteristics - Limits and methods of measurementLimits and Methods of Measurement of Radio Disturbance Characteristics of Information Technology Equipment (1993), Including Amendments A1 (1995) and A2 (1997)".

[7] EN 61000-6-1: "Electromagnetic compatibility (EMC) -- Part 6-1: Generic standards - Immunity for residential, commercial and light-industrial environments".

[8] EN 60950: "Safety of information technology equipment".

[9] CEPT/ERC Recommendation T/R 13-02: "Preferred channel arrangements for fixed services in the range 22.0 - 29.5 GHz".

[10] ETSI EN 300 385: "Electromagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for fixed radio links and ancillary equipment".

[11] ITU-T Recommendation G.821: "Error performance of an international digital connection operating at a bit rate below the primary rate and forming part of an integrated services digital network".

[12] ITU-T Recommendation G.826: "Error performance parameters and objectives for international, constant bit rate digital paths at or above the primary rate".

[13] CEPT/ERC Recommendation 01-02: "Preferred channel arangement for digital fixed service systems operating in the frequency band 31.8 - 33.4 GHz".

[14] CEPT/ECC Recommendation 01-04: "Recommended guidelines for the accommodation and assignment of Multimedia Wireless Systems (MWS) in the frequency band 40.5 - 43.5 GHz".

[15] ITU-T Recommendation G.827: "Availability parameters and objectives for path elements of international constant bit-rate digital paths at or above the primary rate".

[16] ERC Report 99: "The analysis of the coexistence of two FWA cells in the 24.5 – 26.5 GHz and 27.5 – 29.5 GHz bands".

[17] CEPT/ERC Recommendation 01-03: "Use of parts of the band 27.5-29.5 GHz for Fixed Wireless Access (FWA)".

[18] CEPT/ERC Recommendation 00-05: "Use of the band 24.5 - 26.5 GHz for fixed wireless access".

[19] ETSI ETS 300 019-1-4: "Equipment Engineering (EE); Environmental conditions and environmental tests for telecommunications equipment; Part 1-4: Classification of environmental conditions; Stationary use at non-weatherprotected locations".

[20] ETSI EN 301 489 (Series): "ElectroMagnetic compatibility and Radio spectrum Matters (ERM); ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 16: Specific conditions for analogue cellular radio communications equipment, mobile and portable".

[21] ITU-T Recommendation G.783: "Characteristics of synchronous digital hierarchy (SDH) equipment functional blocks".

[22] ITU-T Recommendation G.825: "The control of jitter and wander within digital networks which are based on the synchronous digital hierarchy (SDH)".

[23] ITU-T Recommendation G.831: "Management capabilities of transport networks based on the synchronous digital hierarchy (SDH)".

[24] ETSI ETS 300 132-1: "Equipment Engineering (EE); Power supply interface at the input to telecommunications equipment; Part 1: Operated by alternating current (ac) derived from direct current (dc) sources".

[25] ETSI ETS 300 132-2: "Equipment Engineering (EE); Power supply interface at the input to telecommunications equipment; Part 2: Operated by direct current (dc)".

[26] ITU-T Recommendation M.2100 (Series): "Performance limits for bringing-into-service and maintenance of international PDH paths, sections and transmission systems3.

[27] ETSI EN 301 215-1: "Fixed Radio Systems; Point to Multipoint Antennas; Antennas for point-to-multipoint fixed radio systems in the 11 GHz to 60 GHz band; Part 1: General aspects".

[28] ETSI EN 301 215-2: "Fixed Radio Systems; Point to Multipoint Antennas; Antennas for point-to-multipoint fixed radio systems in the 11 GHz to 60 GHz band; Part 2: 24 GHz to 30 GHz".

[29] ETSI EN 301 215-3: "Fixed Radio Systems; Point to Multipoint Antennas; Antennas for point-to-multipoint fixed radio systems in the 11 GHz to 60 GHz band; Part 3: Multipoint Multimedia Wireless system in 40,5 GHz to 43,5 GHz".

[30] ITU-R Recommendation P.676-5: "Attenuation by atmospheric gases".

[31] ITU-R Recommendation P.835-3: "Reference standard atmospheres

[32] ITU-R Recommendation P.452-10: "Prediction procedure for the evaluation of microwave interference between stations on the surface of the Earth at frequencies above about 0.7 GHz".

[33] CEPT/ERC Recommendation 13-04: "Preferred frequency bands for fixed wireless access in the frequency range between 3 and 29.5 GHz".

# 3 Definitions, symbols and abbreviations

## 3.1 Definitions

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

**Access Point (AP):** generalized equipment consisting of an Access Point Controller (APC) and several Access Point Transceivers (APT)

**cell:** geographical area controlled by an Access Point

**control zone:** part of the DL frame

**DL burst:** transmission event consisting of a channel-symbol-sequence (preamble and the data symbols) corresponding to a given PHY mode transporting one or several FEC-blocks in the optional TDMA zone of the DL frame

**Downlink (DL):** direction from AP to AT

**Downlink channel:** channel transmitting data from APT to AT

**DL map:** MAC message that defines the starting symbols for both TDM and TDMA access by an AT on the DL

**DL MAC frame:** structured data sequences with fixed duration of 1 ms

**FEC-block:** block resulted from the encoding of one or up to four MAC PDUs

**Frame Offset (FO):** time difference between the DL frame and UL frame, selected by the AP in case of FDD mode

**frequency reuse:** ratio between the available frequency carriers to the number of frequency carriers used per sector

**full-duplex:** equipment (e.g. AT) which is capable of transmitting and receiving data at the same time

**guard-time:** time at the beginning or end of each burst to allow power ramping-up and down

**half-duplex:** equipment (e.g. AT) which cannot transmit and receive data simultaneously

**MAC PDU:** data unit exchanged between the DLC and PHY layers, consisting of the MAC PDU header and the MAC PDU payload

**Net Filter Discriminator (NFD):** ratio between the interfering power and portion of the interfering power falling into the victim Rx filter

**PHY mode:** combination of a signal constellation (Modulation alphabet) and FEC parameters (i.e. inner, outer, block-length, etc.)

**preamble:** sequence of channel symbols with a given auto-correlation property assisting modem synchronization and channel estimation

**puncturing:** operation for increasing the coding rate of a convolutional code by not transmitting (= by deleting) some coded bits

**power ramping:** operation performed during the guard time period for power transition from OFF-level to ON-level and vice versa

**sector:** geometrical area resulting from the cell-splitting by the use of a Sector Antenna

**shortening:** operation for decreasing the length of a systematic block code that allows an adaptation to different information bits/bytes sequence length

**Tx/Rx Switching time:** amount of time required to transit from the PHY reception to the PHY transmission or vice versa for H-FDD AT or TDD AP and AT

**TDM-Zone:** part of the DL frame consisting of contiguous TDM-data streams regions corresponding to different PHY modes-regions, starting by the most robust PHY mode

**TDMA-Zone:** part of the DL frame consisting of an optional TDMA data using different PHY modes, where each PHY mode-region is separated with preamble

**tail-bits:** 6 zero bits inserted for trellis termination of a convolutional code in order to force the trellis to go to the zero state

**Uplink (UL):** direction from AT to AP

**UL Map:** MAC message scheduling UL bursts

**UL Burst:** transmission event consisting of a power ramp-up, channel-symbol-sequence (preamble and the data symbols) corresponding to a given PHY mode transporting one or several MAC PDUs in the UL TDMA frame and power ramp-down

**UL Burst Concatenation:** process for concatenation of several UL bursts, where a unique power ramp-up time shall be used at the beginning of the first burst

**Uplink channel:** channel transmitting data from AT to APT

## 3.2 Symbols

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

| | |
|---|---|
| $\alpha$ | Roll-off factor |
| $\beta$ | Primitive element of the Galois Field |
| B | Channel bandwidth in MHz |
| dB | decibel |
| dBm | decibel relative to 1 mW |
| DS | Duplex spacing (fn' - fn) |
| $\Delta$loss | Implementation loss |
| eqloss | Equalization and synchronization loss |
| F | Noise figure in dB |
| $f_c$ | The carrier frequency |
| $f_r$ | The reference frequency in MHz |
| $f_n$ | The centre frequency (MHz) of the radio-frequency slot in the lower half of the band |
| $f_{n'}$ | The centre frequency (MHz) of the radio-frequency slot in the upper half of the band |
| $f_N$ | The Nyquist frequency: $1/(2\ T_s)$ |

| | |
|---|---|
| h(t) | Raised root cosine filter impulse response |
| H(t) | Raised root cosine filter transfer function |
| K | Number of information byte per RS codeword |
| M | Number of bits transmitted per modulated symbol |
| $R_s$ | Symbol rate |
| Rxloss | Receiver branching loss |
| t | Number of error correction capability of a RS code (t=8 here) |
| $T_{samp}$ | Symbol duration after sampling |
| $T_s$ | Channel symbol duration |
| r | Inner code rate (convolutional code rate) |
| φ | Phase |

## 3.3 Abbreviations

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

| | |
|---|---|
| A/D | Analogue/Digital |
| AP | Access Point (base station = BS) |
| APC | AP Controller |
| APT | AP Transceiver |
| ARQ | Automatic Repeat Request |
| AT | Access Termination (terminal = subscriber station SS) |
| ATM | Asynchronous Transfer Mode |
| ATPC | Automatic Transmit Power Control |
| ATTC | Automatic Transmit Time Control |
| AWGN | Additive White Gaussian Noise |
| BBE | Background Block ErrorBCh Broadcast Channel |
| BCH | Bose-Chaudhuri-Hocquenghem (FEC-Code) |
| BER | Bit Error Rate |
| CAZAC | Constant Amplitude Zero Auto Correlation |
| CC | Convolutional code |
| C/I | Carrier to Interference power ratio |
| C/N (CNR) | Carrier to Noise power ratio |
| CL | Convergence Layer |
| CRC | Cyclic Redundancy Check |
| D/A | Digital/Analogue |
| DL | Downlink |
| DLC | Data Link Control |
| ECC | Error Correction Coding |
| EIRP | Effective Isotopic Radiated Power |
| EVM | Error Vector Magnitude |
| FDD | Frequency Division Duplex |
| FEC | Forward Error Correction |
| FO | Frame Offset |
| HA | HIPERACCESS |
| H-FDD | Half-duplex Frequency Division Duplex |
| IDU | Indoor Unit |
| IP | Internet Protocol |
| ISO | International Standards Organization |
| ISOP | Interference Scenario Occurrence Probability |
| IWF | InterWorking Function |
| LAN | Local Area Network |
| LL | Leased Lines |
| MAC | Medium Access Control |
| MSB | Most Significant BitMWS Multimedia Wireless System |
| NFD | Net Filter Discriminator |
| NMS | Network Management System |
| NT | Network Termination |
| ODU | OutDoor Unit |
| OI | Outage Intensity |

| | |
|---|---|
| OSI | Open System Interconnect |
| PDU | Protocol Data Unit |
| PER | Packet Error Rate |
| PHY | PHYsical (layer) |
| PMP | Point to MultiPoint |
| PRBS | Pseudo Random Binary Sequence |
| QAM | Quadrature Amplitude Modulation with square constellation |
| QoS | Quality of Service |
| RF | Radio Frequency |
| RS | Reed-Solomon |
| RT | Radio Termination |
| Rx | Receiver |
| SDU | Service Data Unit |
| SEP | Severely Errored Period |
| SNI | Service Node Interface |
| TDD | Time Division Duplex |
| TDM | Time Division Multiplex |
| TDMA | Time Division Multiple Access |
| TPC | Turbo Product Code |
| TS | Technical Specifications |
| Tx | Transmitter |
| UL | UpLink |
| UNI | User-Network Interface |

# 4 Overview

## 4.0 General

This clause describes an overview of the PHY layer and its relationship with other components of HIPERACCESS.

## 4.1 Point to Multi-Point (PMP) architecture

HIPERACCESS network deployments will potentially cover large areas (i.e. cities). Due to large capacity requirements of the network, millimetre wave spectrum (typically between 11 GHz to 42 GHz) will be used hence limiting transmission ranges to a few kilometres. A typical network will therefore consist of some number of **Cells** each covering part of the designated deployment area. Each cell will operate in a **Point to Multi-Point (PMP)** manner, where an **Access Point (AP)** equipment device (also known as Base Station) located approximately at the cell centre, communicates with a number of **Access Termination (AT)** devices (also known as Terminal or Subscriber Equipment) which are spread within the cell, where the maximum number of ATs per carrier shall not exceed 254 and per sector 256.

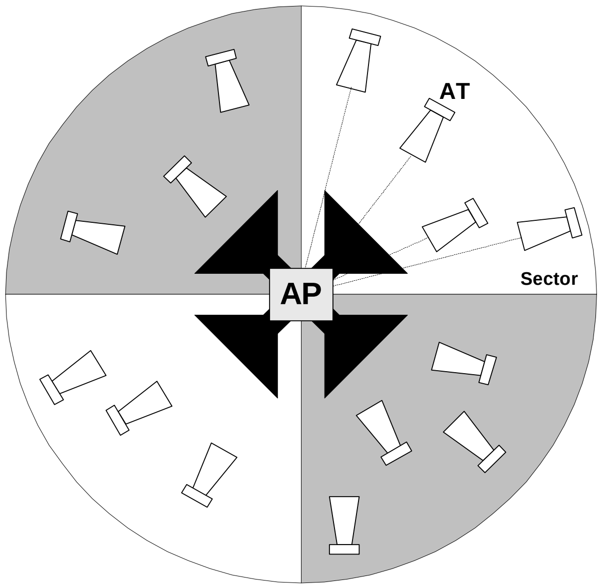



**Figure 1: Example of a cellular configuration (4 X 90° sectors)**

Figure 1 shows a cell partitioning into a small number of **sectors** (i.e. 4, 6 or 8) by using sector azimuth patterned antennas at the AP, increasing spectrum efficiency by the possibility of re-using available RF channels in a systematic manner within the deployment area. It is emphasized that more than one subscriber within the sector may share an RF channel assigned to a specific sector - meaning that the ratio between AT equipment count and AP equipment count is typically a large number.

As Line of Sight (LoS) conditions are essential for millimetre wave communications, cells may overlap in their coverage patterns. The overlap increases the likelihood of LoS conditions hence allowing for better market penetration.

## 4.2 HIPERACCESS reference model and interfaces

The HIPERACCESS radio access system will be deployed to connect user-network interfaces (UNIs) located in and physically fixed to customer premises and to a service node interface (SNI) of a broadband core network (e.g. IP, ATM, LL, etc.).

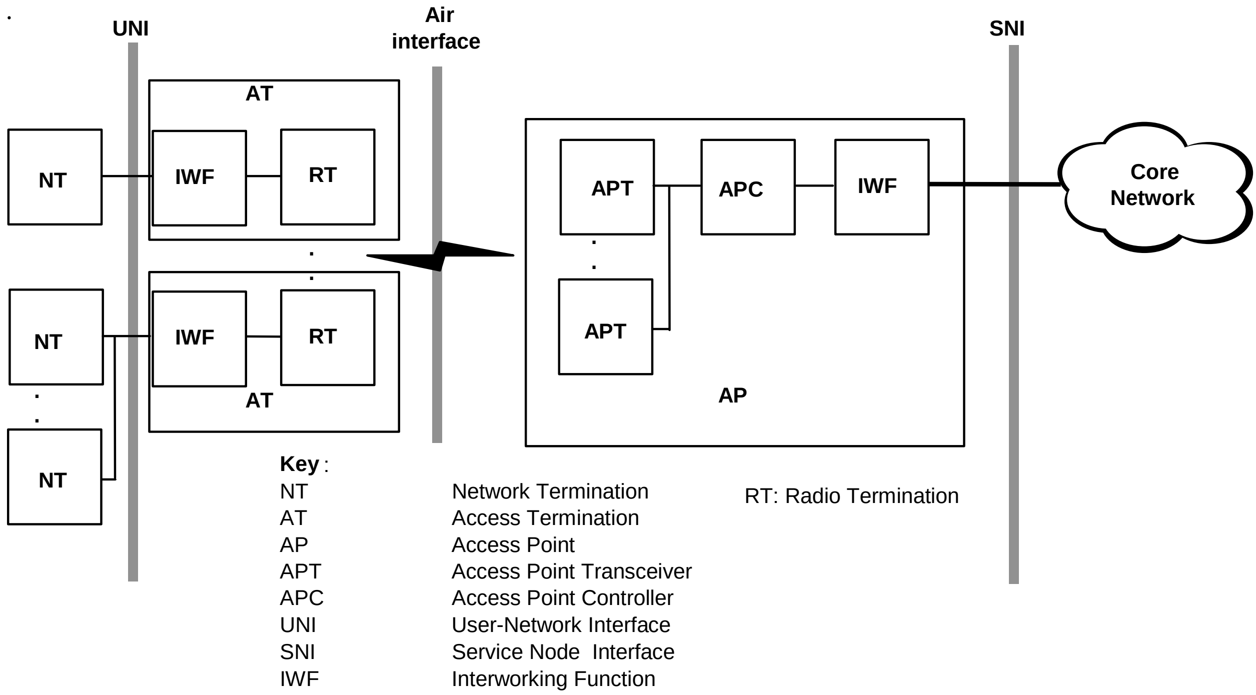



**Figure 2: Simplified HIPERACCESS reference model**

As it is illustrated in figure 2 the AP typically manages communications of more than one sector. For each sector one antenna or more is positioned to cover the deployment region.

The AT antenna is directional, pointed to the serving AP. At AT side, the network termination (NT) interface connects the AT with the local user network (i.e. LAN, TDM).

The AT and the AP are connected via the Air interface, where its PHY layer specification will be described in the present document. The data link control (DLC) layer specifications are specified in a separate document (TS 102 000) (see bibliography).

# 4.3 Duplex Schemes (FDD, H-FDD and TDD)

## 4.3.1 General

As the air-interface communication channel between the AP and ATs is bi-directional, **downlink** (AP to AT direction) and **uplink** (AT to AP direction) paths must be established utilizing the spectrum resource available to the operator. Two duplex schemes are available, one is frequency domain based and the other one is time domain based.

## 4.3.2 FDD

**Frequency Division Duplex (FDD)** partitions the available spectrum into a downlink frequency block and an uplink frequency block (see figure 3). An RF channel is actually a pair of channels, one from the downlink block and one from the uplink block, hence downlink and uplink transmissions are established on separate and independent radio channels. In HIPERACCESS both downlink and uplink channels shall be equal in size, 28 MHz wide (see clause 5.2.2).

Within the allocated spectrum, downlink and uplink channel pairs are separated equally simplifying the required radio architecture. In some designated spectrum assignments a guard band between the downlink and uplink blocks is provisioned yet in other cases the existence of a guard band will depend on specific radio capabilities and on RF deployment planning.

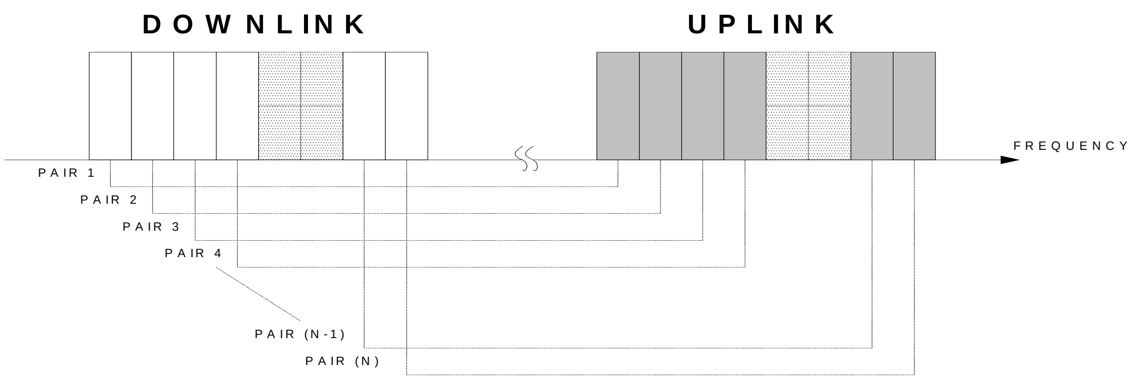



**Figure 3: FDD frequency assignment**

### 4.3.2.1 Half-FDD

In the FDD case, if an AT radio equipment is limited to a half-duplex operation (i.e. transmission and reception cannot occur simultaneously, see figure 4) then relaxation of some design parameters is possible (i.e. isolation) hence AT cost reduction is facilitated. The DLC layer acknowledging AT limitations should schedule downlink reception events and uplink transmission events accordingly. Furthermore, the AP recognizes in this case the fact that switching from transmission operation to reception operation (and vice versa) at the AT is not immediate (i.e. ramp up of power output is needed).

It is emphasized that the half-duplex operation is an AT feature only. The AP has a different impact on the deployment cost and on system capacity. Note that in addition to AT burst transmission capability half-duplex operation requires burst reception capability as well.

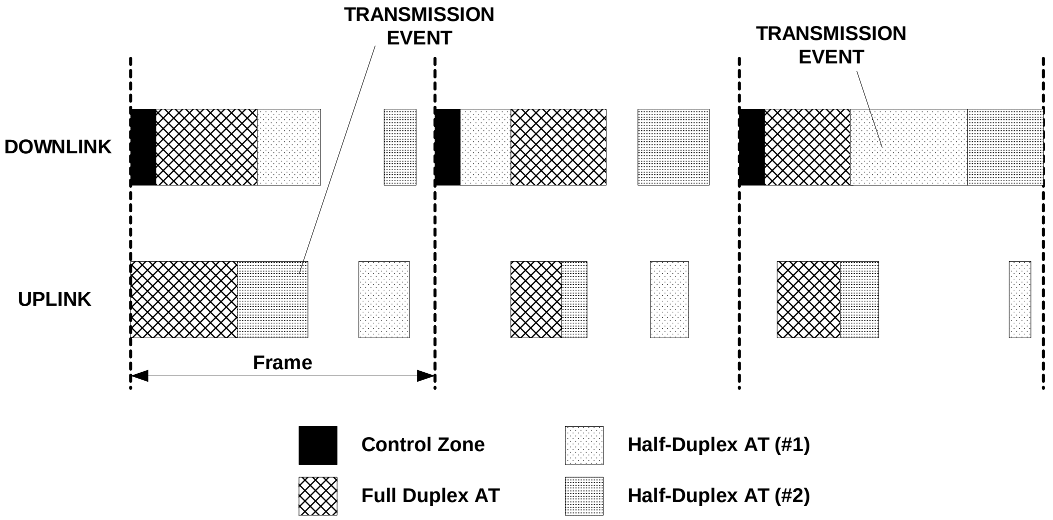



**Figure 4: H-FDD scenario**

In HIPERACCESS, half-duplex operation in the AT equipment is an optional feature. However, AP equipment shall support AT equipment, which has implemented this feature.

### 4.3.3 TDD

In contrast to FDD**, Time Division Duplex (TDD)** uses a single RF channel for downlink and uplink communications (see figure 5). The downlink and uplink transmissions are established by time-sharing the radio channel where downlink and uplink transmission events never overlap. The channel size is 28 MHz wide like in one direction of the FDD case.

In the TDD case both the AP and AT equipments are half-duplex. The AP establishes a frame-based transmission and allocates portion of its frame for downlink purposes and the remainder of the frame for uplink purposes. The ratio between the allocated time for downlink transmissions and the time allocated for uplink transmissions is configurable. This ratio will be identical for a given deployment region in order to maximize capacity requirements by frame synchronization of all cells. Note that for single or isolated cells, requirements for frame synchronization could be relaxed due to lower interference conditions.

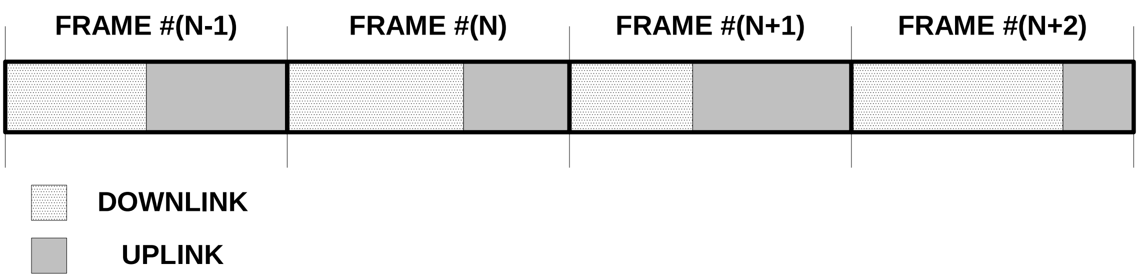



**Figure 5: TDD framing**

Note that the TDD operation shall use identical parameters to those of FDD. This is straightforward as the FDD operation consists of fixed length framed transmissions (see clause 4.5), which is capable of supporting burst transmissions as in the case of FDD half-duplex ATs.

## 4.4 Adaptive PHY modes

Typically, when a carrier is shared by more than one AT, modulation and coding parameters are set according to the AT which has the greatest path loss or is exposed to the greatest amount of interference. Coupled with the fact that the operator wishes to maximize coverage, the modulation and coding choice in these cases will be robust yet spectrum inefficient (i.e. 4QAM with a low rate code).

Even if the cell size is greatly reduced, potentially allowing for higher order modulation schemes (i.e. 64QAM) to be used, the self-interference conditions (due to the multi-cell deployment) will dominate and prevent service to some large number of ATs (i.e. coverage dead spots).

HIPERACCESS uses adaptive PHY modes for solving this problem. A PHY mode is a predefined combination of modulation and coding parameters. In contrast with other transmission systems where one PHY mode dominated the entire downlink transmission, in the HIPERACCESS case more than one PHY mode is used occupying different parts of the downlink frame. In the uplink different ATs use different PHY modes according to their individual link conditions.

The AP controls the use of a specific PHY mode. If for example link conditions deteriorate (i.e. rain) then it is expected that more ATs will be assigned to more robust PHY modes. If the link recovers, then it is expected that more ATs will be assigned to more spectrum efficient PHY modes within their link limitations. Although in some deployment scenarios uplink transmissions can employ similar techniques to those of the downlink, there will be some cases where it will be useful to limit the choices of PHY modes for the uplink due to a different, random-like interference behaviour, especially apparent when the available spectrum is re-used aggressively.

In HIPERACCESS, the modulation format shall be QAM based. The forward error correction scheme shall be based on a Reed-Solomon code concatenated with a convolutional code with no interleaving.

# 4.5 Multiplexing technique and frame structures

## 4.5.1 Downlink

The downlink transmitted data to different ATs is multiplexed in the time domain. As HIPERACCESS employs adaptive PHY modes, a frame consists of a few TDM regions (see figures 6 and 7). Each TDM region is assigned with a specific PHY mode. Only ATs capable of receiving (i.e. demodulating) the assigned PHY mode may find their downlink data multiplexed in the associated TDM region. For simplifying the demodulation process, TDM regions are allocated in a robustness descending order. For example, an AT with excellent link conditions, which is assigned to a spectrum efficient PHY mode, starts its reception process at the beginning of the frame and continues through all TDM regions (using a more robust PHY mode), ending its reception process with its associated TDM region. An AT with worse link conditions will be assigned to a more robust PHY mode and its reception process will end before the AT of the previous example. Note that in any case coarse acquisition and synchronization is performed once per frame for all ATs, using the DL frame preamble.

The TDM regions location within a frame is broadcast in a downlink Map, similarly to the uplink Map (see clause 5.3.4), at the beginning of the frame.

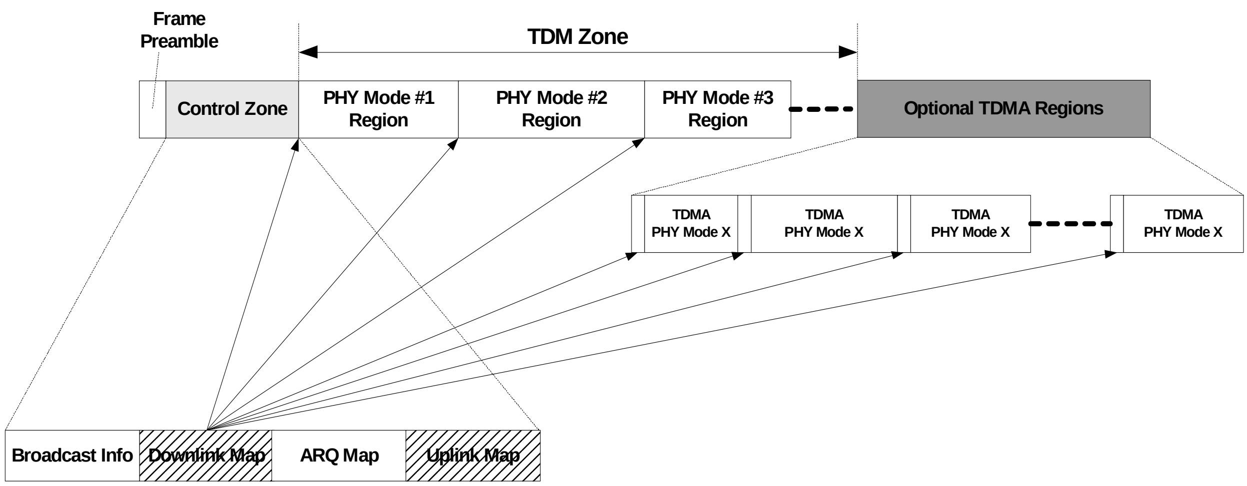



**Figure 6: FDD Downlink framing and multiplexing**

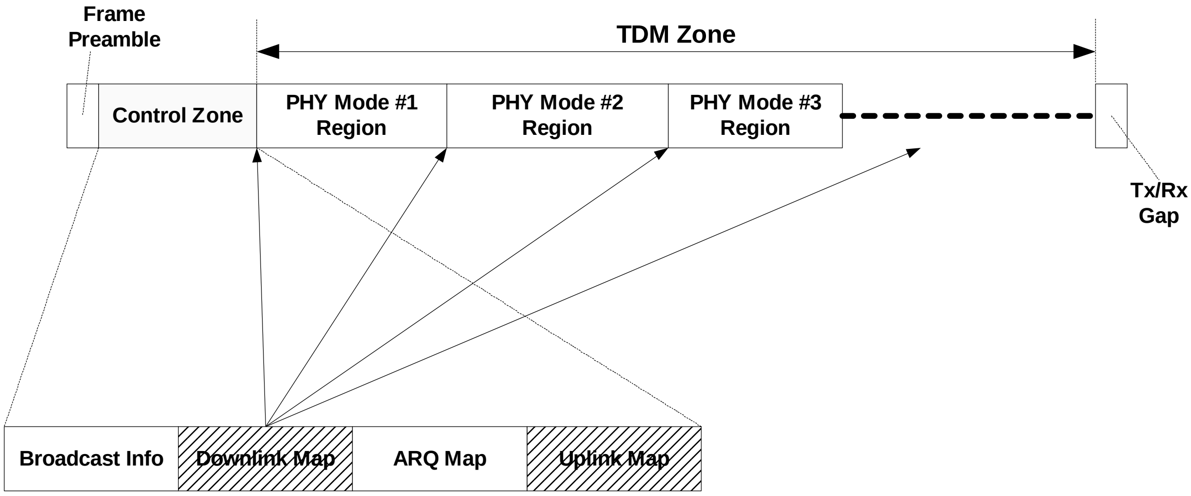



**Figure 7: TDD Downlink framing and multiplexing**

TDMA transmissions are optionally present on the downlink. In this scheme, an AT may be assigned to receive downlink transmissions either in a TDM region as previously discussed or in an attached TDMA region. The TDMA region allocations are broadcast as part of the downlink Map. With no downlink TDMA option, a half-duplex AT has limited opportunities to transmit as it is forced to demodulate the downlink continuously from the beginning of the downlink frame and once it transmits it must wait for the next downlink frame to re-synchronize. With the downlink TDMA option the AT may seek downlink reception opportunities immediately after it ceases its uplink transmission within the current downlink frame. The AP scheduling procedures should use the downlink TDMA feature as it increases channel utilization and minimizes latencies. Note that a TDMA region may serve more than one AT by time division multiplexing downlink data of several ATs. In addition, note that the DL frame duration in case of FDD is 1 ms, where in case of TDD, it can be lower.

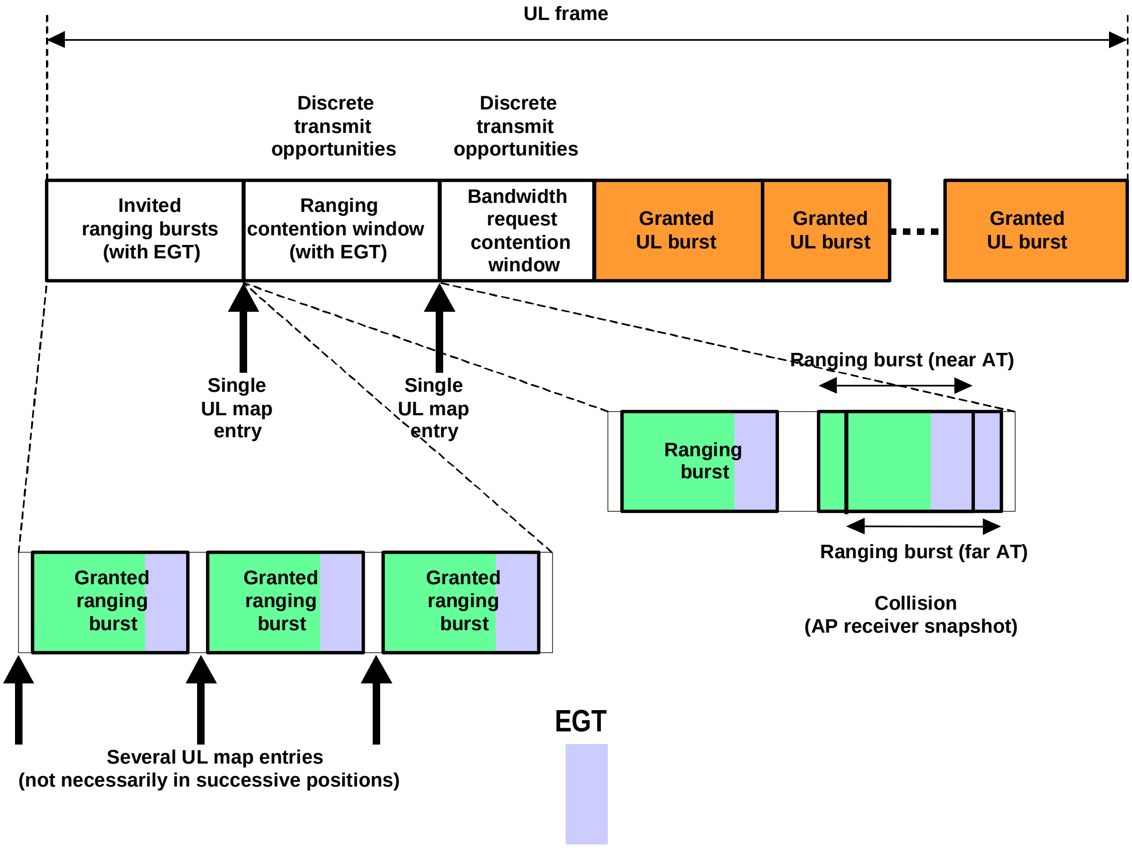
## 4.5.2 Uplink

As more than one AT is sharing the same RF channel, the AP must employ techniques controlling the access of ATs. In the uplink case, the TDMA (Time Division Multiple Access) shall be used. After an AT has been registered with the system, its uplink bursts are scheduled by the AP. The scheduled transmissions have time coordinates which uniquely define when the AT shall begin and end its transmission. The schedule data for uplink transmission is organized in an Uplink Map broadcast by the downlink. The AP scheduler accommodates AT limitations for transmitter ramp up.

An AT can transmit in an unsolicited, contention based manner, only in the following 2 cases:

a) For first initialization purposes.

b) For responding to multicast or broadcast polls (for bandwidth request).




NOTE:
- Not all windows are present in all frames.
- The order of windows is just an example.
- Arbitrary positions in case of several granted ranging bursts are possible.

**Figure 8: Uplink framing and multiplexing**

In both cases a time window for accomplishing these tasks is broadcast in the uplink Map as well. In the first case it is assumed that the AT has received downlink transmissions from the AP and has stabilized its radio parameters (i.e. synchronization) yet has not necessarily calibrated its timing alignment (due to propagation delays), hence the time window length should accommodate by using an extended guard time (EGT) to handle with the far most user AT served by the AP. Timing alignment is performed through the initialization process. In the second case it is assumed that the AT has registered with the system.

## 4.6 Conceptual block diagram of the PHY layer

A PHY implementation includes transmission and reception functional components. For the downlink, transmission occurs in the AP and reception in the AT. For the uplink, transmission occurs in the AT and reception in the AP. Although very similar in concept, note that the AP equipment in general handles more than one RF channel and more than one user (AT), hence its actual architecture will be different. Further note that the description in this clause is conceptual only and implementers are free to combine different functional entities or split other blocks as they choose, as some of the blocks and their specific connectivity to other blocks are not mandated by the present document (i.e. equalizer).

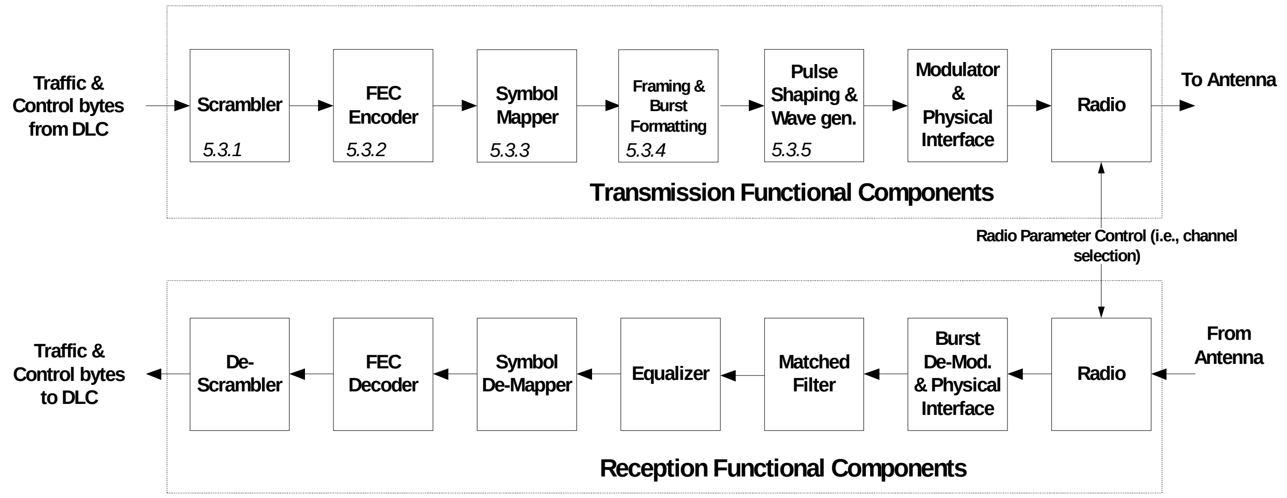



**Figure 9: PHY layer conceptual block diagram**

Transmission operation from the PHY perspective starts with a stream of traffic and control bytes sent from the DLC layer. This data will be randomized using a scrambler (see clause 5.3.1). In HIPERACCESS the coding and modulation are separated, hence first the data is protected by FEC encoding (see clause 5.3.2). The resulting data is then mapped into symbols (see clause 5.3.3) according to the designated modulation density. These modulated symbols and the corresponding preambles are multiplexed to form a frame or a burst (in the downlink case the preamble exists only at the beginning of the frame or at the beginning of each TDMA region, see clause 5.3.4). The resulting symbols after framing or burst formatting are pulse shaped and wave formed (i.e. root raised cosine filter, see clause 5.3.5) and are forwarded through a physical interface (i.e. D/A) to the radio transmitter.

Reception operation from the PHY perspective starts with receiving an analog signal from the radio receiver. As an example, it could be a base-band (i.e. Zero-IF) signal or some low IF frequency. The physical interface (i.e. A/D) converts the signal to the digital domain and a demodulator identifies the preamble existence and the reception process may properly initiate. A matched filter is used to extract symbol values and an equalizer structure can be used to further enhance signal quality. Symbols are translated to actual bits by constellation de-mapping. A FEC decoder corrects channel errors and may be used to identify data integrity. Any randomization done by the scrambler in the transmission process is removed and finally the received control and traffic bytes are sent to the higher DLC-layer for continued processing.

# 4.7 Traffic and Control Bytes from the DLC- to the PHY layer

The DLC layer shall provide two types of MAC PDUs for the UL PHY layer, i.e. to the AT-PHY and one type of MAC PDU and additional control zone bytes sequences for the DL PHY layer, i.e. to the AP-PHY. Note that these control and traffic bytes from the DLC- to the PHY layer are equivalent to the PHY SDU bytes as introduced in TS 102 000 (see bibliography).

## 4.7.1 Downlink

### 4.7.1.1 DL MAC PDU (PHY SDU)

Only one type of MAC PDU (or PHY SDU) with a fixed length of 54 bytes shall be provided from the DLC layer to the PHY layer. This MAC PDU is made of two parts: a 3-byte long header and a 51-byte long payload that may contain data, signalling or dummy bytes.

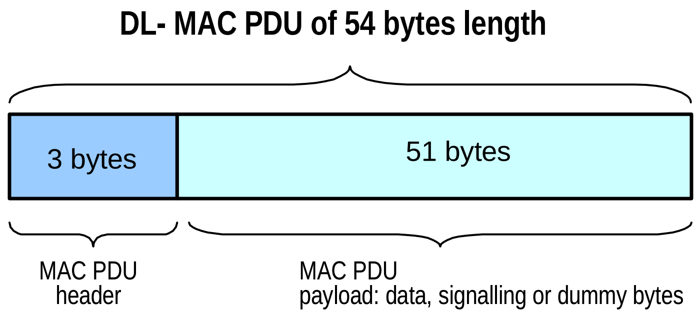



**Figure 10: Downlink MAC PDU structure**

#### 4.7.1.2 DL control zone

The control zone is consisted of four parts: DL broadcast information, DL Map, ARQ-Map and UL Map. The number of bytes per control zone is variable. The control zone shall be transmitted once per DL frame (see clause 5.3.4).

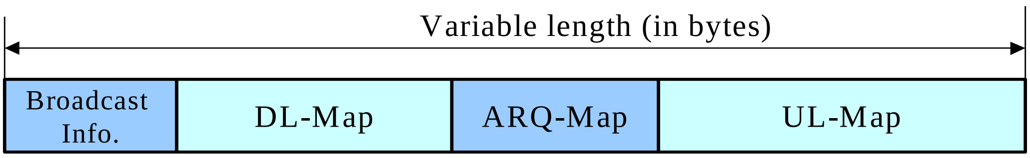



**Figure 11: DL control zone structure**

### 4.7.2 Uplink

Two types of MAC PDUs (or PHY SDU) shall be provided from the DLC layer to the PHY layer.

#### 4.7.2.1 UL long MAC PDU (PHY SDU)

The first type is a long MAC PDU with a length of 55 bytes. This MAC PDU is made of two parts: a 4-byte long header and a 51-byte long payload that may contain data, signalling or dummy bytes.

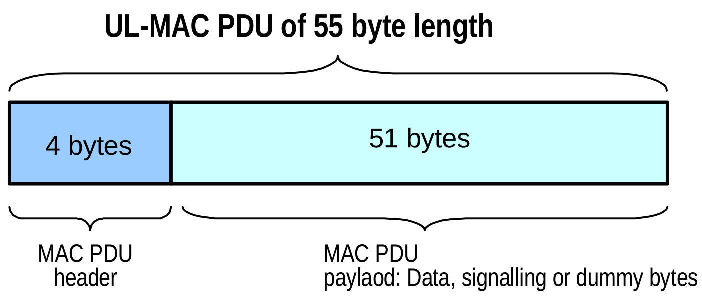



**Figure 12: Uplink Long MAC PDU structure**

#### 4.7.2.2 UL short signalling MAC PDU (PHY SDU)

The second type is the short signalling MAC PDU of 12 bytes. This short MAC PDU is made of two parts: a 4-byte long header and a 8-byte long payload that carries only signalling bytes.

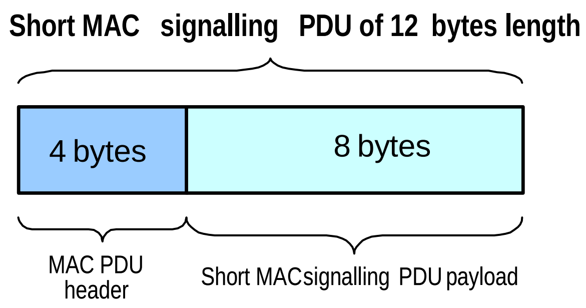



**Figure 13: Uplink short signalling MAC PDU structure**

# 5 Physical layer

## 5.1 Introduction

The architecture of the PHY layer is determined mainly by the following important HA features:

- Single carrier transmission.
- Support of different duplex schemes: FDD, H-FDD and TDD.
- Use of adaptive coding and modulation.

The aim of this clause is to describe in details the HA PHY layer air interface specification. After given an overview on the related system issues, the following items will be covered in details:

the PHY baseband functions which comprise the scrambling, FEC encoding, modulation, framing and multiplexing and filtering; and

the Radio Frequency (RF) issues (carrier frequencies, RF masks, spurious emission, power issues, etc.).

## 5.2 General aspects

### 5.2.1 Channel model for HIPERACCESS

Two sources of physical impairments are considered when specifying the HIPERACCESS propagation channel model:

- Rain fading, resulting in frequency *flat fading* effects;
- Multi-path propagation, resulting in frequency *selective fading* effects.

#### 5.2.1.1 Rain fading

Maximum flat fading slope assumed for modelling heavy rain phenomena is 20 dB/s.

#### 5.2.1.2 Multi-path propagation

The multi-path propagation will be modelled by a set of *discrete-time* channels, to be considered in specifying and testing HIPERACCESS systems. The three different channel models adopted for HIPERACCESS are given in table 1.

**Table 1: HA-channel model parameters (normalized parameters)**

| Channel | Equation | Sampling period ($T_{samp}$) |
|---|---|---|
| $C_0$ | C(z) = 1, i.e. only AWGN | - |
| $C_1$ | $C(z) = 0{,}981 – 0{,}194 \times z^{-1}$ | $T_s$ |
| $C_2$ | $C(z) = 0{,}981 – 0{,}194 \times e^{-j\varphi} \times z^{-1}$, $\varphi = \pi/5$ | $T_s$ |

### 5.2.2 Channelization scheme

HIPERACCESS is optimized for carrier frequencies greater than 11 GHz. The exact carrier frequencies employed in HA are given in clause 5.5.1.

#### 5.2.2.1 Channel spacing

The nominal carrier frequencies for HIPERACCESS systems shall be spaced 28 MHz apart, in both uplink and downlink direction.

The frequency resolution required for channel selection for both AP and AT, e.g. nominal carrier frequency selection resolution in both UL and DL directions shall be in accordance with table 2 [9], [14].

**Table 2: HA frequency resolution**

| | All carrier frequencies > 11 GHz, except 28 GHz-CEPT | 28 GHz CEPT carrier frequency |
|---|---|---|
| **Frequency resolution** | 1 MHz | 0,5 MHz |

#### 5.2.2.2 Channel planning

The HA channel plans are in accordance with the recommendations issued by CEPT/ERC, dealing with the Fixed Services frequency arrangements. In particular see [9], [14] covering all frequencies up to 32 GHz.

Note that the ERC draft recommendation for FDD in the 40,5 GHz to 43,5 GHz is defining the frequency block plan, while the specific HIPERACCESS "virtual" channel plan, able to overlay the ERC block plan, is described in annex B. For the TDD case, either the same HIPERACCESS "virtual" channel plan as previously mentioned or the default ERC 1 MHz slot plan (in cases where local regulatory considerations support a mixture of wireless technologies in the MWS band which are not tied to a block based arrangement) can be used.

### 5.2.3 PHY layer system features summary

A summary of the HA PHY layer features is presented in table 3.

**Table 3: Main features of the HA PHY layer**

| **System Issues** | **Characteristics** |
|---|---|
| Topology | Point to Multi-point with cell sectorization |
| Multiple access scheme | - Downlink: TDM, with optional TDMA<br>- Uplink: TDMA |
| Max number of ATs per carrier/sector | 254/256 |
| **Transmission QoS** | **Characteristics** |
| Bit error rate, BER | BER < $10^{-11}$ |
| Delay<br>PHY delay | ITU-T Recommendations (ITU-T Recommendation I.356) (Informative)<br>The PHY processing delay shall not exceed 200 channel symbols duration. This delay does not include any pipelining delay |
| **Base-band Physical Layer Issues** | |
| Bandwidth | 28 MHz (UL and DL) |
| Transmission technique | Single Carrier, both DL and UL |
| Filter | Squared Root Raised cosine filter, roll off = 0,25 |
| Symbol rate | 22,4 Mbaud |
| Modulation schemes DL | 4QAM, 16QAM, and optional 64QAM |
| Modulation scheme UL | 4QAM, optional 16QAM |
| Coding scheme for UL and DL | Concatenated RS + Convolutional (mandatory)<br>Optional Turbo codes for UL |
| Adaptive coding and modulation UL<br>Adaptive coding and modulation DL | Burst by burst for different AT<br>Frame by frame for given AT |
| Number of DL PHY modes | Two sets available (second optional), up to four modes per set |
| Number of UL PHY modes | Two sets available, up to three modes per set |
| Types of UL bursts | Three types of Bursts: Long burst (Data or long Signalling), short burst (short signalling) and Ranging burst |
| Preamble for each UL burst | 16 or 32 Symbols (CAZAC) (depending on the AP capability) |
| Guard time for each UL burst | 8 symbols |
| Preamble for each DL TDMA burst | 16 Symbols (CAZAC) |
| Preamble for each DL frame | 32 Symbols (CAZAC) |
| Frequency synchronization | UL carrier should be locked to the DL carrier |
| **RF Issues** | |
| Carrier frequencies | All carrier frequencies greater than 11 GHz |
| Duplex method | FDD, TDD |
| Antenna base station | TM4 specifications (e.g. 45, 60 and 90°) |
| Antenna terminal | TM4 specifications |
| Output power at maximum setting | 15 dBm for APT and 14 dBm for AT |
| Max. EIRP AP (Class-1) | 33 dBmi + 3 dB accuracy |
| Max. EIRP AT (42 GHz) | 51 dBmi + 3 dB accuracy |

### 5.2.4 Environmental, safety and electromagnetic conditions

In table 4, the parameters for the environmental, safety and electromagnetic conditions are summarized.

**Table 4: HA environmental, safety and electromagnetic conditions**

| **Environmental conditions** | **Recommendations** |
|---|---|
| Operation, ODU | ETS 300 019-1-4 Class 4.1 [19] |
| Operation, IDU | ETS 300 019-1-4 Class 3.1 [19] |
| **Electromagnetic and safety conditions** | |
| Electromagnetic compatibility | EN 300 385 [10], EN 301 489 [20] |
| Immunity to electromagnetic interference | EN 61000-6-1 [7] |
| Immunity to electromagnetic radiation | EN 55022 [6] |
| Electrical Safety | EN 60950 [8] |

### 5.2.5 Supports (Recommendations)

**Table 5: Supports**

| Supports | Recommendations |
|---|---|
| Synchronization | ITU-T Recommendations (G.783 [21] and G.831 [23] or G.825 [22]) |
| Power supply | ETS 300 132-1 [24] and ETS 300 132-2 [25] |

## 5.3 Base-band parameters

### 5.3.1 Data scrambling

All MAC PDUs and control zone bytes shall be scrambled with a length $2^{15}$ -1 Pseudo Random Binary Sequence bits, in accordance with the configuration depicted in figure 14. The polynomial S(x) for the Pseudo Random Binary Sequence (PRBS) shall be:

$$S(x) = x^{15} + x^{14} + 1$$

The same scrambler shall be used to scramble transmit data and to de-scramble received data. All MAC PDU bytes belonging to a given frame are transmitted by using the same initial state for scrambling. The scrambling will affect the whole transmission except the preamble symbols.

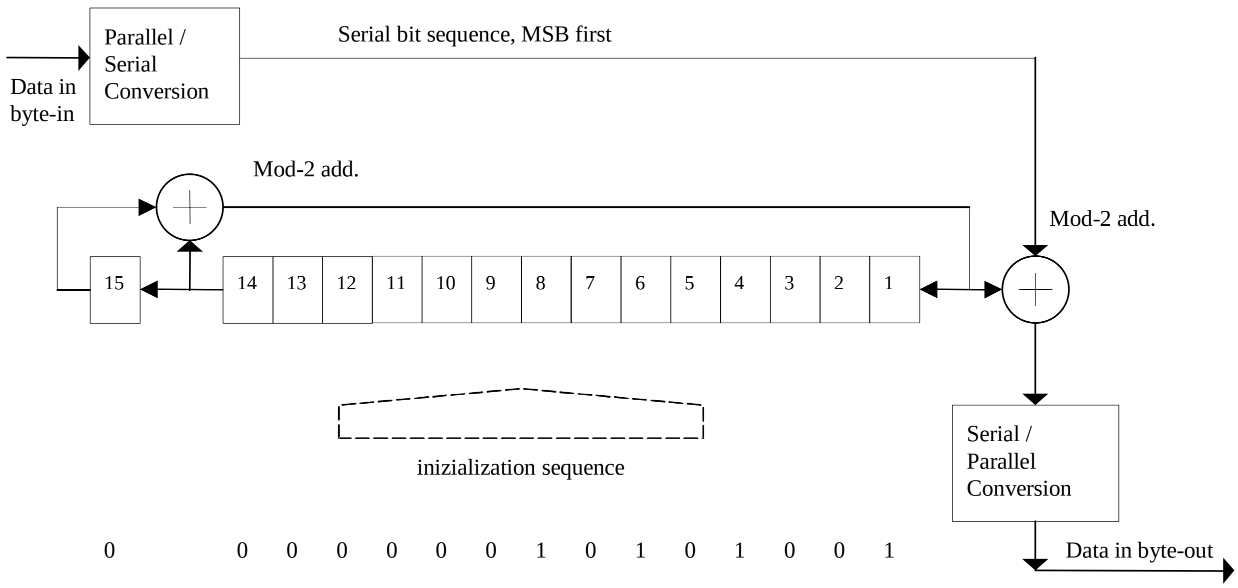



**Figure 14: Scrambler schematic diagram**

The initialization shall be based on the following "100101010000000" PRBS-pattern. The initialization process shall follow the following procedure:

- For the UL, the initialization shall be done at the beginning of every burst, excluding the UL preamble.
- In case of UL burst concatenation, the initialization shall be done after the first preamble, where the scrambling operation shall exclude all other preambles.
- For the DL the initialization shall be done at the beginning of each frame, excluding the frame-preamble. Additionally, in case of optional TDMA, the initialization shall be done per each TDMA region, excluding the DL TDMA preamble.

## 5.3.2 Error control

### 5.3.2.1 Forward error correction

Two channel coding schemes are adopted in HA for forward error correction. The first one, being mandatory is based on a concatenated Reed-Solomon with convolutional coding. The second optional coding scheme is based on Turbo code that shall be used only for the UL. Both coding schemes can provide different code-rates.

#### 5.3.2.1.1 Concatenated Reed-Solomon and convolutional coding

The mandatory FEC coding scheme is based on a concatenated coding scheme. The outer code shall be a shortened Reed-Solomon (RS) code and the inner code shall be a punctured convolutional code (CC) (see figure 15). The coding scheme is flexible. It provides different outer (from 0,43 to 0,93) and inner code rates (from 1/2 to 1, where 1 means no use of inner CC, i.e. only outer RS code). For detailed coding procedure of DL control zone bytes refer to clause 5.4.5.

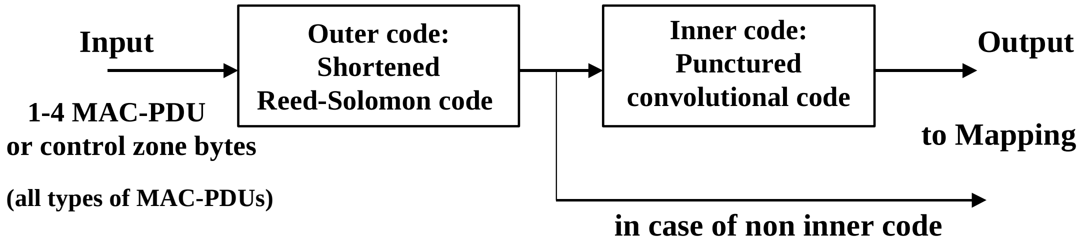



**Figure 15: Mandatory channel coding scheme**

##### 5.3.2.1.1.1 Outer code characteristics

The outer code shall be a shortened Reed-Solomon RS (K + 16, K, t=8) code that can transmit different number of MAC PDUs or control zone bytes. This code shall be derived from the original systematic Reed-Solomon RS(255, 239, t=8) code, able to correct up to t=8 byte errors.

The field generator polynomial of the Reed-Solomon code over GF(256) shall be:

$$P(x) = x^8 + x^4 + x^3 + x^2 + 1$$

The code generator polynomial shall be: $g(x) = (x + \beta^0)(x + \beta^1)...(x + \beta^{15})$, where $\beta$ = 02 in Hex is the primitive element of the Galois Field GF(256).

#### 5.3.2.1.1.2 Inner code characteristics

The inner code shall be a punctured convolutional code that shall provide from the mother code memory 6 (64 states), rate 1/2, a wide range of higher inner code rates r, e.g. r = 2/3, 5/6 and 7/8. The generator polynomial of the mother convolutional code shall be: $G_1 = 171_{oct}$, $G_2 = 133_{oct}$.

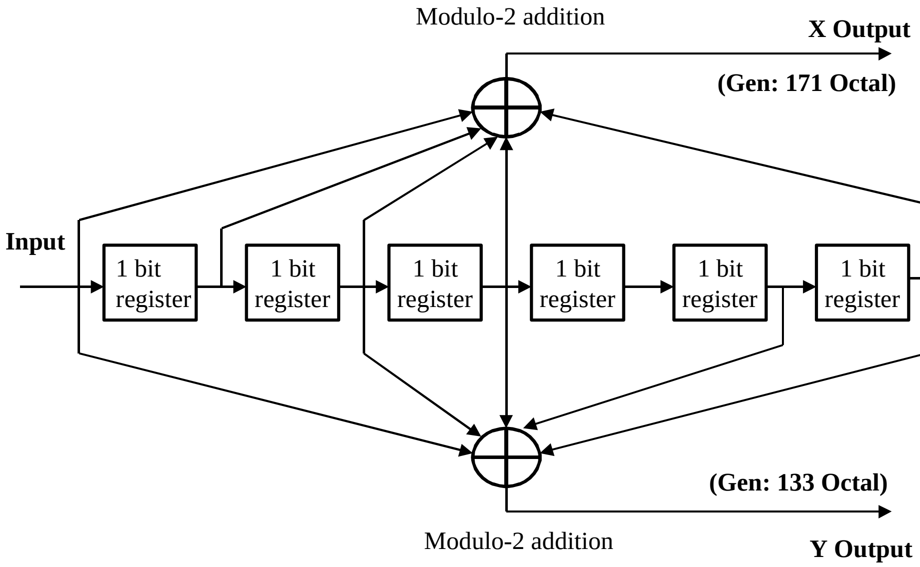



**Figure 16: Inner mother convolutional code of rate 1/2 with memory 6**

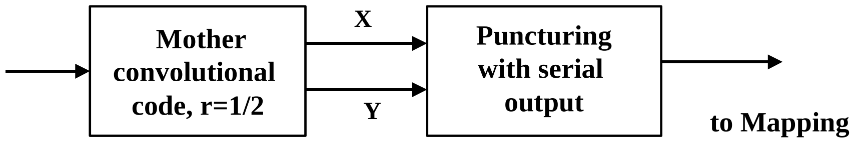



**Figure 17: Punctured convolutional code**

**Table 6: The puncturing patterns of the inner convolutional code ($X_1$ is sent first)**

| Inner code rate, r | Puncturing patterns | Transmitted sequences (after parallel to serial conversion) |
|---|---|---|
| 1/2 | X: 1<br>Y: 1 | $X_1$ $Y_1$ |
| 2/3 | X: 1 0<br>Y: 1 1 | $X_1$ $Y_1$ $Y_2$ |
| 5/6 | X: 1 0 1 0 1<br>Y: 1 1 0 1 0 | $X_1$ $Y_1$ $Y_2$ $X_3$ $Y_4$ $X_5$ |
| 7/8 | X: 1 0 0 0 1 0 1<br>Y: 1 1 1 1 0 1 0 | $X_1$ $Y_1$ $Y_2$ $Y_3$ $Y_4$ $X_5$ $Y_6$ $X_7$ |

The puncturing patterns of the convolutional code for different inner code rates r are given in table 6. In this table "0" means that the coded bits shall not be transmitted (i.e. punctured) and "1" means that the coded bits shall be transmitted. Note that each matrix has two rows and several columns; where the puncturing vector for each row corresponds to the outputs of the encoder X and Y, respectively (see figure 16).

#### 5.3.2.1.1.3 Coding Procedure for DL and UL Transmission

Due to the use of adaptive coding and modulation, the channel coding operation is performed as follows, valid for the UL and DL (see figure 18), except the DL control zone which is specified in clause 5.4.5.

One or several MAC PDUs (up to four) shall be mapped to the information part, yielding K bytes of the outer code RS(255,239, t=8).

Since the total number of MAC PDU's bytes, i.e. K bytes will be smaller than 239 bytes, 239K bytes shall be filled by zero bytes at the beginning of the information part of the RS-codeword. The systematic RS (255, 239, t=8) Reed-Solomon coding shall be applied. After RS coding, the systematic structure of RS code allows to shorten the code, i.e. remove the inserted 239-K zero bytes before transmission. Then, each shortened RS codeword of length K + 16 bytes shall be serial bit converted (MSB first). If inner coding is not used, the shortened RS codeword containing [(K + 16) X 8] bits shall be submitted directly to the modulation by inserting padding bits (depending on the used coding and modulation) in order to guarantee an integer number of modulated symbol.

In case of inner coding, at the end of each serial bit converted RS-codeword 6 zero tailbits shall be inserted for inner code trellis termination purposes.

Then each $[(K + 16) \times 8 + 6_{Tailbits}]$ bits shall be encoded by the inner convolutional mother binary code of rate 1/2. After convolutional coding, the puncturing operation shall be applied following the used inner code rate r for a given PHY mode, that results in a total of $[(K + 16) \times 8 + 6_{Tailbits}] / r$ bits. Finally, the punctured bits shall be parallel-serial converted and shall be submitted to the modulation/Mapping unit. However, before modulation, some padding bits (depending on the used coding and modulation) shall be inserted in order to provide an integer number of modulated symbol.

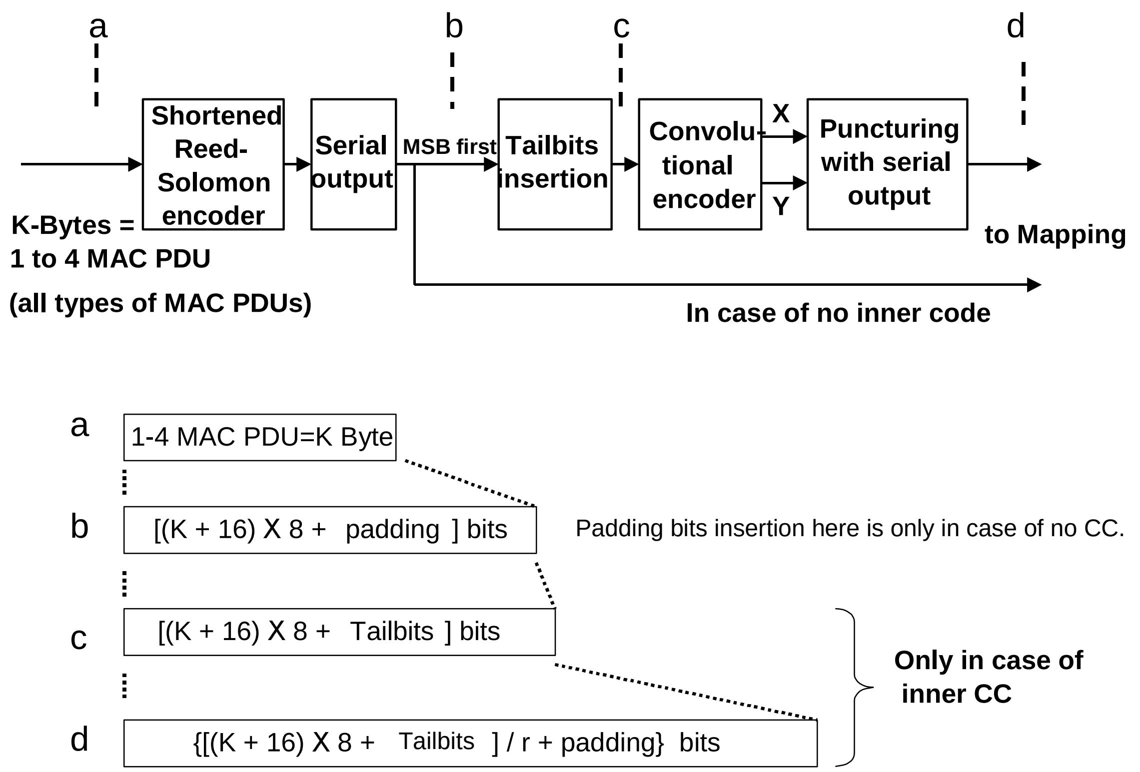



**Figure 18: Channel coding procedure per FEC-block for UL and DL transmission**

By shortening the systematic RS code, the RS codeword length can be adapted to transmit different number of MAC PDUs per codeword. For the downlink up to 4 X MAC PDUs per codeword shall be transmitted.

In addition, as the uplink frame structure will be governed by the AP, then for each terminal different number of MAC PDUs could be reserved by the MAC-layer. In this case the RS code may transmit only one or several MAC PDUs per codeword, where the RS code will be shortened to transmit one data MAC PDU of 55 Bytes using RS(71,55, t=8) or up to four MAC PDUs using RS(236, 220, t=8) code.

Note that in case of only RS coding, the FEC block is equivalent to a RS codeword transmitting one or up to 4 MAC PDUs and some additional padding bits. In case of concatenated coding scheme (outer RS and inner convolutional code), the FEC block will contain the redundancy of one RS codeword (transmitting up to 4 MAC PDUs), the inner code redundancy, the 6 trellis termination bits and the padding bits, where the trellis termination bits are inserted before inner coding at the end of the RS codeword.

### 5.3.2.1.2 Optional uplink FEC scheme: Turbo product code

The optional FEC coding scheme shall be a Turbo Product Code (TPC), that will be applied only for the UL. This coding scheme uses product codes in a matrix form for two-dimensional coding.

For Turbo coding option the following conditions shall be respected:

- Turbo encoding shall be optional for the AT and Turbo decoding shall be optional for the AP.
- The Turbo capability should be reported from AT to the AP during first initialization.
- The PHY modes based on Turbo coding shall provide the same spectral efficiency as the mandatory coding scheme by providing better C/N values.
- The cell coverage is determined by the mandatory PHY modes, where Turbo coding should provide higher system capacity with no advantage on the system cost.
- The Turbo code shall also support the capability of error detection at the APT for ARQ-purposes as well.

#### 5.3.2.1.2.1 Error detection capability

Before TPC encoding the 1 to 4 MAC PDUs shall be encoded with a Cyclic Redundancy Check (CRC) code with 24 parity bits (see figure 19). The following procedure is performed:

1) Preset the shift register to all ones.
2) After serial parallel conversion, shift the data part with [(1 to 4) 55 $\times$ 8] bits through the shift register with the MSB first.
3) Add the 24 parity bits of the CRC code to the message.

The CRC code shall be the remainder generated by the module 2 division by the following polynomial:

$$G(x) = X^{24} + X^{10} + X^{9} + X^{6} + X^{4} + X + 1$$

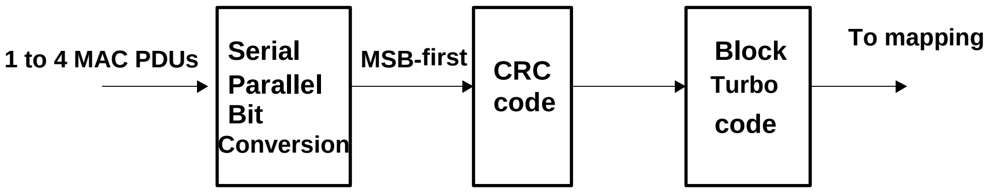



**Figure 19: General block diagram of block Turbo encoder**

#### 5.3.2.1.2.2 Turbo Product Code (TPC) characteristics

The matrix form of the two-dimensional code is depicted in figure 20.

The K_R information bits in the rows shall be encoded into N_R bits, by using a binary block (N_R, K_R, t_R) code. After encoding the data bits using a row code with parameters (N_R, K_R), the N_R columns shall be encoded using another block code (N_C, K_C, t_C) called "column code", where the row error correction coding bits of the row code (Row ECC bits) shall also be encoded.

The overall block size of such a product code is $N = N\_R \times N\_C$, the total number of information bits $K = K\_R \times K\_C$ and the code rate is $R = R\_R \times R\_C$, where $R\_i = K\_i/N\_i$ with i = R, C. The Hamming distance of the product code is $d = d\_R \times d\_C$.

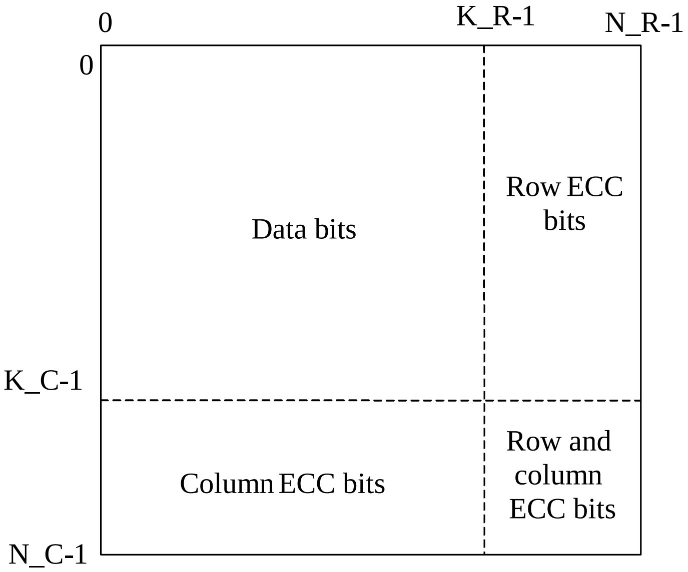



**Figure 20: Turbo Product Code matrix**

The binary block codes employed shall be (t_C or t_R = 1 and t_C or t_R = 2) extended BCH-codes (Bose-Chaudhuri-Hocquenghem) or single parity codes.

The generator polynomials of the BCH codes used in TPCs are given in table 7.

**Table 7: Generator polynomials of the BCH codes**

| N | K | Generator polynomial | Hamming distance |
|---|---|---|---|
| 15 | 11 | $x^4 + X + 1$ | 3 |
| 31 | 26 | $x^5 + x^2 + 1$ | 3 |
| 63 | 57 | $x^6 + X + 1$ | 3 |
| 63 | 51 | $x^{12} + x^{10} + x^8 + x^5 + x^4 + x^3 + 1$ | 5 |
| 127 | 120 | $x^7 + x^3 + 1$ | 3 |

Shortening shall be used to adapt the code rate and frame size to the requirements. Three parameters are used to shorten a block:

- Sx gives the number of suppressed rows;
- Sy gives the number of suppressed columns;
- Sb gives the number of additional suppressed bits (on the first not suppressed row).

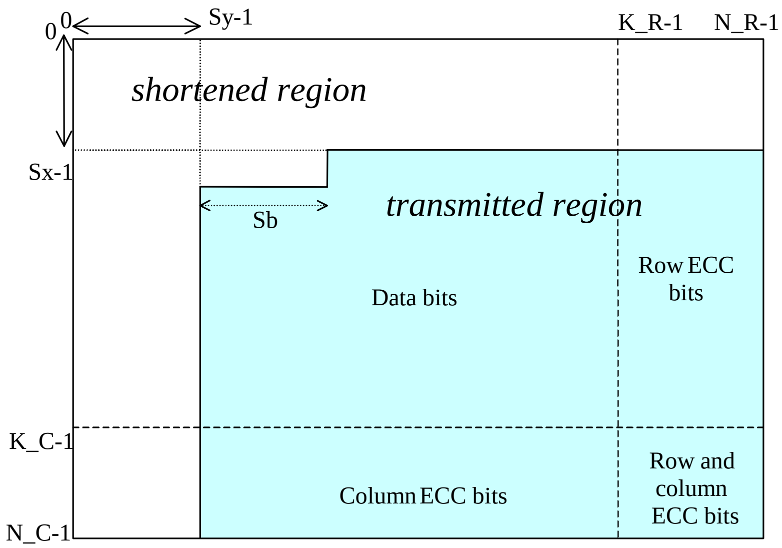



**Figure 21: Structure of shortened block**

#### 5.3.2.1.2.3 Hyper codes: extension of TPC

Hyper codes are an extension of the Turbo Product Codes that have performance improvements for very little reduction in the coding rate. The principle is to add a line to the transmitted region of the encoded TPC matrix. It is noted here that all of the schemes incorporating Hyper codes have the number Sb of additional suppressed bits set to zero. The (N_R - Sy) elements of this additional line shall be obtained using a parity code along the diagonals of the encoded TPC matrix.

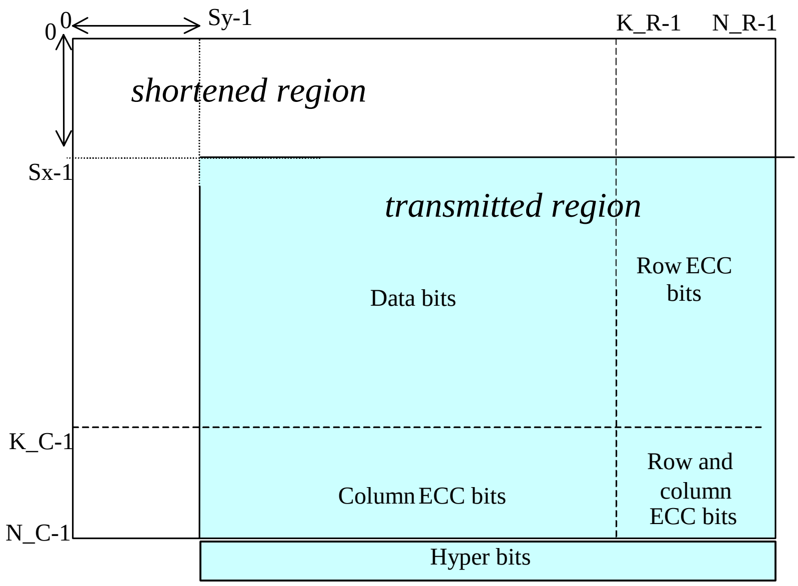



**Figure 22: Structure of encoded block including Hyper code**

If the transmitted region of the TPC block is considered to be on a cylinder with the rows going around the cylinder and the columns up and down the cylinder as in figure 23, then the Hyper axis shall simply be formed by applying a (N_C – Sx + 1, N_C - Sx) parity code along the diagonals starting at each element on the top row. In this way, a row of (N_R – Sy) parity bits is formed which takes place as a new cylinder at the bottom.

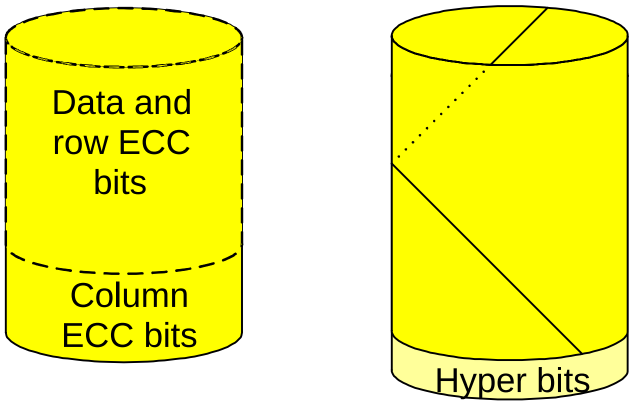



**Figure 23: Exemplifying the Hyper code formation**

Looking again at figure 22, label the bits as $x_{0,0}$ in the top left to $x_{(N\_C\text{-}Sx),(N\_R\text{-}Sy)}$ in the bottom right, then the Hyper parity bits ($h_0$, $h_1$, … , $h_{(N\_R\text{-}Sy)-1}$) can be found by the equation:

$$h_i = \sum_{j=0}^{N\_C-Sx-1} (x_{j,(j+i+((N\_C-Sx)-(N\_R-Sx)) \bmod (N\_R-Sy)}), i = 0,\ldots,(N\_R-Sy)-1$$

5.3.2.1.2.4 Coding Procedure for UL Transmission

Due to the use of adaptive coding and modulation, the channel coding operation is performed as follows:

After CRC coding, one or several MAC PDUs (up to four) shall be mapped to the information part, yielding K = [(1 to 4) × 55 × 8 + 24] bits.

Since the total number of K bits can be smaller than the dimension K_R × K_C of the information part of the TPC matrix, Sx rows and Sy columns shall be suppressed. Then Sb bits shall be suppressed on the first not suppressed row.

Since the size N_R × N_C (or N_R × (N_C + 1)) in case of hyper codes of the encoded TPC block shall be different from the size of the coded block obtained with the mandatory FEC coding scheme for the same information part size K, padding bits shall be inserted to match this size.

### 5.3.2.2 ARQ support

The Automatic Retransmission Request (ARQ) functionality is foreseen for HIPERACCESS uplink direction. In order to make possible the ARQ implementation, some suitable means to detect and mark all UL MAC PDU containing errors shall be supported by the PHY layer inside APT.

For each decoded FEC-block (containing 1 to 4 MAC PDUs) the RS decoder at APT side shall provide a flag to be activated when in presence of erroneous UL MAC PDU.

The ARQ shall not be applied for the DL.

## 5.3.3 Signal constellations and mapping

The modulation shall be based on Quadrature Amplitude Modulation (QAM) with $2^M$ points constellation, where M is the number of bits transmitted per modulated symbol. The general principle of modulation scheme is illustrated in figure 24, which is valid for both uplink and downlink.

For the downlink 4QAM (M = 2) and 16QAM (M = 4) are mandatory and 64QAM (M = 6) optional. For the uplink 4QAM is mandatory and 16QAM optional. The constellation mappings shall be based on Gray mapping. Figures 25, 26 and 27 and tables 9, 10 and 11 define the constellation points for the different modulation schemes. In these tables the B(m), m = 1, .. M, denotes the modulation bit order before serial to parallel conversion (1 first and M last).

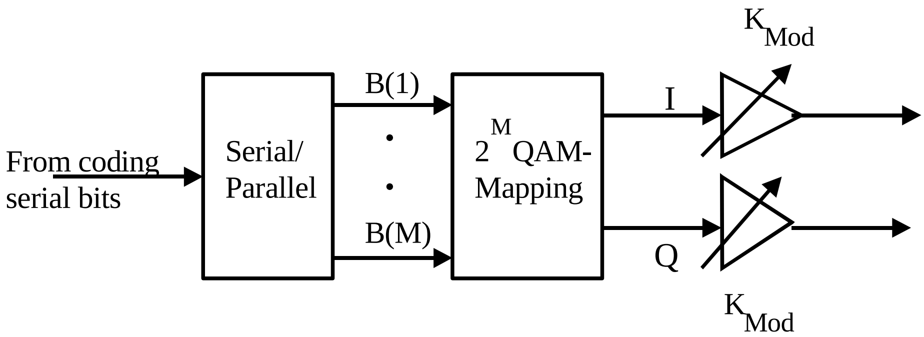



**Figure 24: Signal mapping block-diagram**

The complex modulated symbol shall take the value I + jQ from the $2^M$ points constellation. The output complex values are formed by multiplying the resulting (I + jQ) value by a normalization factor $K_{MOD}$: (I + jQ) X $K_{MOD}$. The normalization factor $K_{MOD}$ depends on the modulation as prescribed in table 8. The purpose of the normalization factor is to achieve the same average power for all mappings. The normalization factor $K_{MOD}$ should indicate this fact and no implementation rule. In practical implementations an approximate value of the normalization factor may be used, as long as the device conforms to the general transmitter and receiver performance requirements specified in the present document.

**Table 8: Modulation dependent normalization factor $K_{MOD}$**

| Modulation | $K_{MOD}$ |
|---|---|
| 4QAM | 1 |
| 16QAM | 1/√5 |
| 64QAM | 1/√21 |

### 5.3.3.1 4QAM with Gray mapping (mandatory for uplink and for downlink)

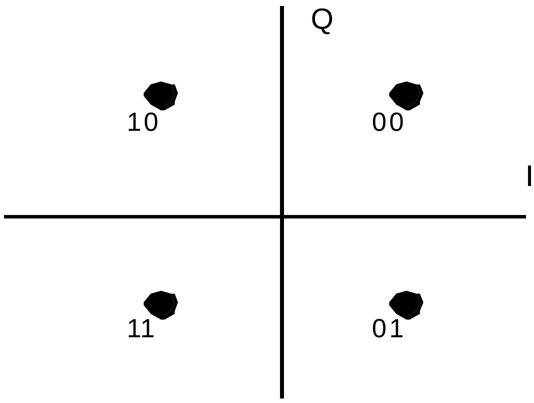



**Figure 25: 4QAM constellation mapping**

**Table 9: Bits-mapping to 4QAM symbols**

| B(1) | B(2) | I | Q |
|---|---|---|---|
| 0 | 0 | 1 | 1 |
| 0 | 1 | 1 | -1 |
| 1 | 0 | -1 | 1 |
| 1 | 1 | -1 | -1 |

### 5.3.3.2 16QAM with Gray mapping (mandatory for downlink, optional for uplink)

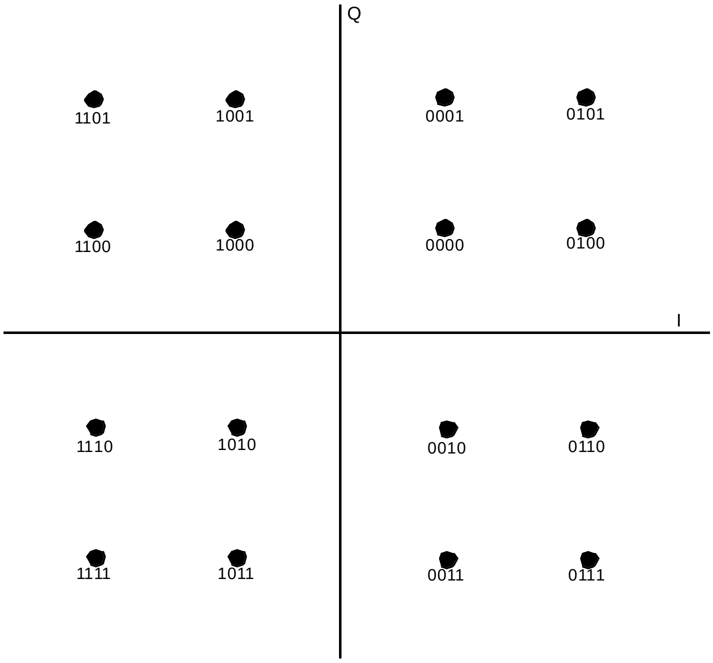



**Figure 26: 16QAM constellation mapping**

**Table 10: Bits-mapping to 16QAM symbols**

| B(1) | B(2) | B(3) | B(4) | I | Q |
|---|---|---|---|---|---|
| 0 | 1 | 0 | 1 | 3 | 3 |
| 0 | 1 | 0 | 0 | 3 | 1 |
| 0 | 1 | 1 | 0 | 3 | –1 |
| 0 | 1 | 1 | 1 | 3 | –3 |
| 0 | 0 | 0 | 1 | 1 | 3 |
| 0 | 0 | 0 | 0 | 1 | 1 |
| 0 | 0 | 1 | 0 | 1 | –1 |
| 0 | 0 | 1 | 1 | 1 | –3 |
| 1 | 0 | 0 | 1 | –1 | 3 |
| 1 | 0 | 0 | 0 | –1 | 1 |
| 1 | 0 | 1 | 0 | –1 | –1 |
| 1 | 0 | 1 | 1 | –1 | –3 |
| 1 | 1 | 0 | 1 | –3 | 3 |
| 1 | 1 | 0 | 0 | –3 | 1 |
| 1 | 1 | 1 | 0 | –3 | –1 |
| 1 | 1 | 1 | 1 | –3 | –3 |

### 5.3.3.3 64QAM with Gray mapping (optional and only for downlink)

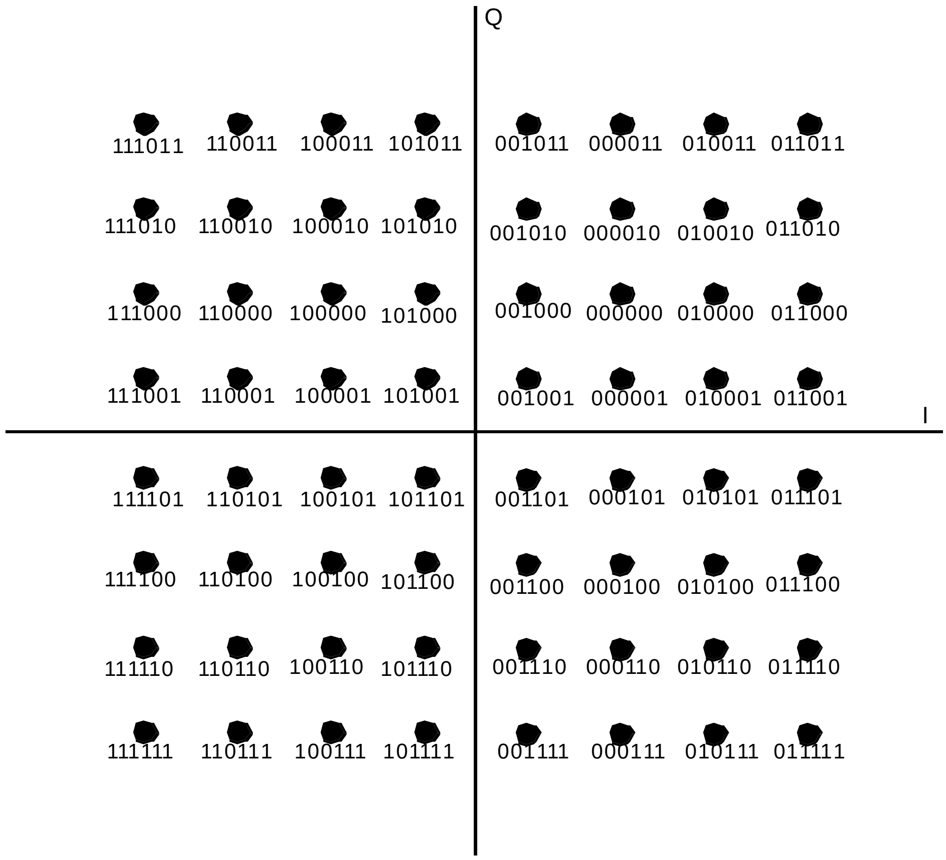



**Figure 27: 64QAM constellation mapping**

**Table 11: Bits-mapping to 64QAM symbols (optional)**

| B(1) | B(2) | B(3) | B(4) | B(5) | B(6) | I | Q |
|---|---|---|---|---|---|---|---|
| 0 | 1 | 1 | 0 | 1 | 1 | 7 | 7 |
| 0 | 1 | 1 | 0 | 1 | 0 | 7 | 5 |
| 0 | 1 | 1 | 0 | 0 | 0 | 7 | 3 |
| 0 | 1 | 1 | 0 | 0 | 1 | 7 | 1 |
| 0 | 1 | 1 | 1 | 0 | 1 | 7 | –1 |
| 0 | 1 | 1 | 1 | 0 | 0 | 7 | –3 |
| 0 | 1 | 1 | 1 | 1 | 0 | 7 | –5 |
| 0 | 1 | 1 | 1 | 1 | 1 | 7 | –7 |
| 0 | 1 | 0 | 0 | 1 | 1 | 5 | 7 |
| 0 | 1 | 0 | 0 | 1 | 0 | 5 | 5 |
| 0 | 1 | 0 | 0 | 0 | 0 | 5 | 3 |
| 0 | 1 | 0 | 0 | 0 | 1 | 5 | 1 |
| 0 | 1 | 0 | 1 | 0 | 1 | 5 | –1 |
| 0 | 1 | 0 | 1 | 0 | 0 | 5 | –3 |
| 0 | 1 | 0 | 1 | 1 | 0 | 5 | –5 |
| 0 | 1 | 0 | 1 | 1 | 1 | 5 | –7 |
| 0 | 0 | 0 | 0 | 1 | 1 | 3 | 7 |
| 0 | 0 | 0 | 0 | 1 | 0 | 3 | 5 |
| 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 |
| 0 | 0 | 0 | 0 | 0 | 1 | 3 | 1 |
| 0 | 0 | 0 | 1 | 0 | 1 | 3 | –1 |
| 0 | 0 | 0 | 1 | 0 | 0 | 3 | –3 |
| 0 | 0 | 0 | 1 | 1 | 0 | 3 | –5 |
| 0 | 0 | 0 | 1 | 1 | 1 | 3 | –7 |
| 0 | 0 | 1 | 0 | 1 | 1 | 1 | 7 |

| B(1) | B(2) | B(3) | B(4) | B(5) | B(6) | I | Q |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 1 | 0 | 1 | 0 | 1 | 5 |
| 0 | 0 | 1 | 0 | 0 | 0 | 1 | 3 |
| 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 |
| 0 | 0 | 1 | 1 | 0 | 1 | 1 | –1 |
| 0 | 0 | 1 | 1 | 0 | 0 | 1 | –3 |
| 0 | 0 | 1 | 1 | 1 | 0 | 1 | –5 |
| 0 | 0 | 1 | 1 | 1 | 1 | 1 | –7 |
| 1 | 0 | 1 | 0 | 1 | 1 | –1 | 7 |
| 1 | 0 | 1 | 0 | 1 | 0 | –1 | 5 |
| 1 | 0 | 1 | 0 | 0 | 0 | –1 | 3 |
| 1 | 0 | 1 | 0 | 0 | 1 | –1 | 1 |
| 1 | 0 | 1 | 1 | 0 | 1 | –1 | –1 |
| 1 | 0 | 1 | 1 | 0 | 0 | –1 | –3 |
| 1 | 0 | 1 | 1 | 1 | 0 | –1 | –5 |
| 1 | 0 | 1 | 1 | 1 | 1 | –1 | –7 |
| 1 | 0 | 0 | 0 | 1 | 1 | –3 | 7 |
| 1 | 0 | 0 | 0 | 1 | 0 | –3 | 5 |
| 1 | 0 | 0 | 0 | 0 | 0 | –3 | 3 |
| 1 | 0 | 0 | 0 | 0 | 1 | –3 | 1 |
| 1 | 0 | 0 | 1 | 0 | 1 | –3 | –1 |
| 1 | 0 | 0 | 1 | 0 | 0 | –3 | –3 |
| 1 | 0 | 0 | 1 | 1 | 0 | –3 | –5 |
| 1 | 0 | 0 | 1 | 1 | 1 | –3 | –7 |
| 1 | 1 | 0 | 0 | 1 | 1 | –5 | 7 |
| 1 | 1 | 0 | 0 | 1 | 0 | –5 | 5 |
| 1 | 1 | 0 | 0 | 0 | 0 | –5 | 3 |
| 1 | 1 | 0 | 0 | 0 | 1 | –5 | 1 |
| 1 | 1 | 0 | 1 | 0 | 1 | –5 | –1 |
| 1 | 1 | 0 | 1 | 0 | 0 | –5 | –3 |
| 1 | 1 | 0 | 1 | 1 | 0 | –5 | –5 |
| 1 | 1 | 0 | 1 | 1 | 1 | –5 | –7 |
| 1 | 1 | 1 | 0 | 1 | 1 | –7 | 7 |
| 1 | 1 | 1 | 0 | 1 | 0 | –7 | 5 |
| 1 | 1 | 1 | 0 | 0 | 0 | –7 | 3 |
| 1 | 1 | 1 | 0 | 0 | 1 | –7 | 1 |
| 1 | 1 | 1 | 1 | 0 | 1 | –7 | –1 |
| 1 | 1 | 1 | 1 | 0 | 0 | –7 | –3 |
| 1 | 1 | 1 | 1 | 1 | 0 | –7 | –5 |
| 1 | 1 | 1 | 1 | 1 | 1 | –7 | –7 |

## 5.3.4 Framing and burst formatting

### 5.3.4.1 Frame structure

AP and AT transmissions are structured in fixed length frames. The frame length is 1 ms. The uplink and downlink frames shall be aligned in time; from AP point of view the uplink frame shall start with a given frame offset (FO) with respect to the downlink frame start. The minimum value of the FO shall be 1/4 frame length. The maximum value for this offset FO is 1 ms. The resolution of the frame offset value shall be 1/16 ms (1400 channel symbols). The alignment is necessary for proper bandwidth allocation management as performed by the DLC layer. The exact time difference between the DL frame and UL frame shall be selected by the AP in case of FDD mode.

### 5.3.4.1.1 FDD case

#### 5.3.4.1.1.1 Downlink

In the downlink case, a frame starts with a preamble of 32 symbols (repetition of 2 X 16 CAZAC Sequences) (see figure 28 in case of TDM and see figure 29 in case of TDMA). A control zone follows the preamble containing some broadcast information, downlink Map, ARQ-Map and uplink Maps. The Maps indicate events (i.e. location and duration within a frame). In the downlink case the Map (DL Map) defines the TDM zone and optionally a TDMA zone. For the uplink the Map (UL Map) defines signalling events and specific user transmission events.

A TDM zone consists of different PHY mode regions by descending robustness order (i.e. 4QAM precedes 16QAM). Each PHY mode region time-multiplexes data associated with different users capable of demodulating and decoding the associated PHY mode. As the number of addressed users within a PHY mode varies and such does their instantaneous downlink data quota, the PHY mode region duration varies from frame to frame.

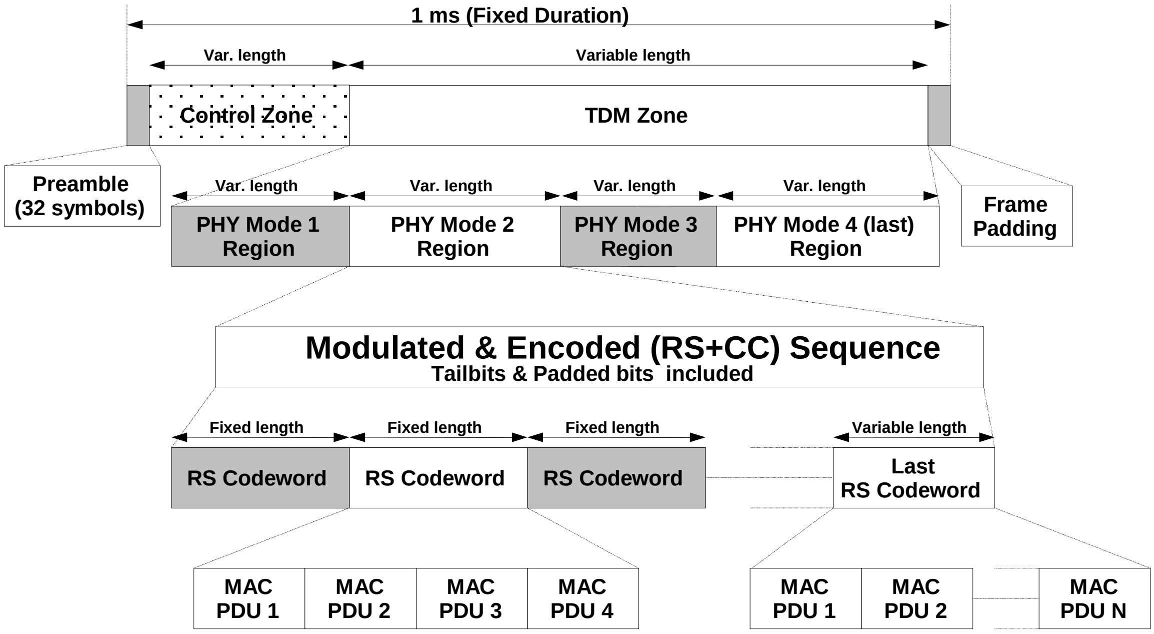



**Figure 28: Detailed downlink frame structure, without TDMA option (N≤4)**

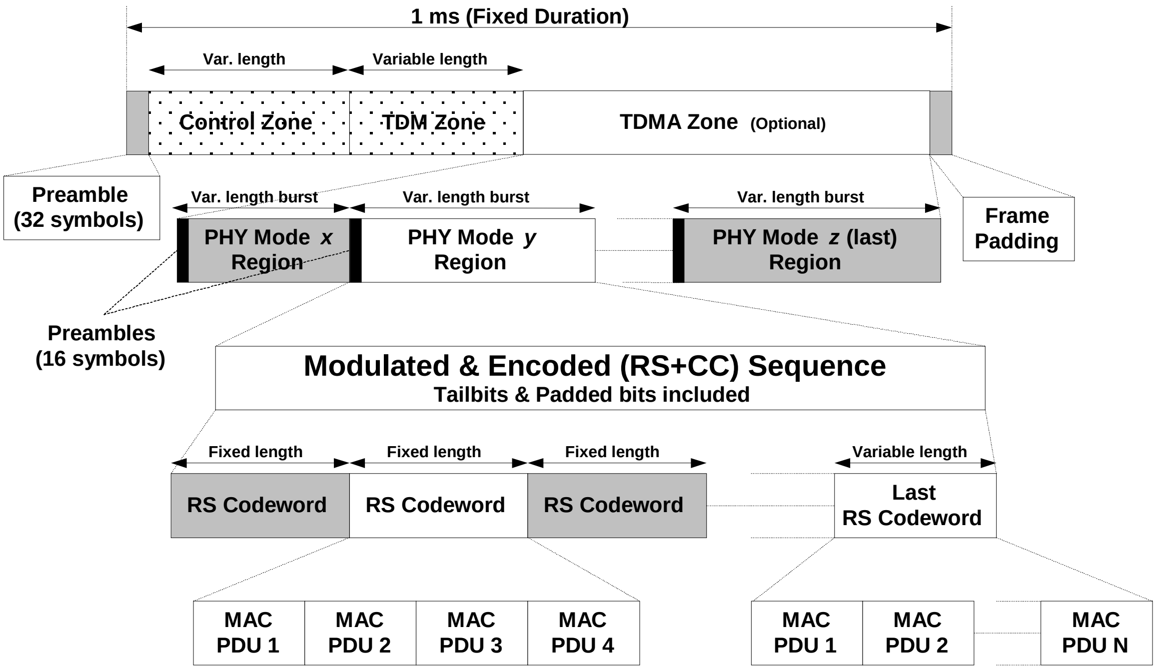



**Figure 29: Detailed downlink frame structure, with TDMA option (N≤4)**

Optionally, a TDMA zone follows the TDM zone. Similarly to the TDM zone, the TDMA zone consists of different PHY mode regions with following differences:

1) No specific robustness order will be observed.

2) Each PHY mode region starts with a short preamble of 16 symbols.

Note that the TDMA zone is intended to be used by half duplex ATs. The half duplex AT is expected to demodulate and decode the beginning of the frame containing the control zone. Depending on its recent uplink transmission event, it is expected that the half duplex AT will switch back to downlink reception and recover its data in a TDMA PHY mode region suitable for its link conditions. The short preamble is intended to assist the half duplex AT to fine tune synchronization parameters.

Each PHY mode region transmits several FEC-blocks, where each FEC block consists of data which is concatenated (RS+CC) encoded using a RS codeword encapsulating up to 4 MAC PDUs (except the last RS codeword).

The end of the frame may require padding for filling it up completely.

#### 5.3.4.1.1.2 Uplink

The uplink consists of two zones:

1) Signalling.

2) AT Traffic.

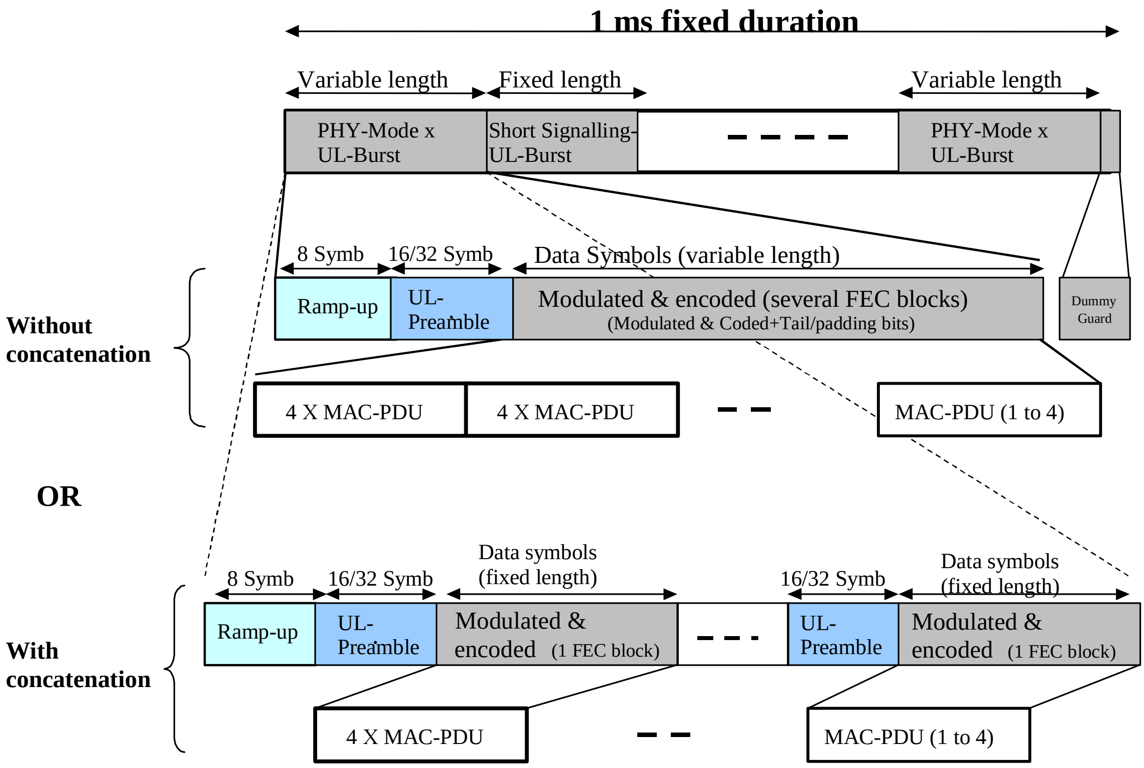



**Figure 30: Detailed uplink frame structure**

The above zone location within a frame is indicated by the uplink Map which is broadcast by the downlink in the control zone.

The signalling burst is typically used for unsolicited AT transmissions (i.e. initialization) or UL ATPC and PHY mode change messages. The AT burst consists of scheduled events related to the bandwidth allocation process in the AP. An AT, where the uplink Map has indicated the existence of an uplink transmission event for it, is expected to transmit its data in the indicated time window which provisions sufficient time for AT transmitter ramp-up. The PHY mode used by the AT for the transmission is specified as well by the uplink Map. The AT begins its transmission with a preamble with length of 16 or 32 symbols, depending on the AP capability that will be negotiated during the first initialization phase.

An AT burst may include more than one FEC blocks hence similar to the downlink, four MAC PDUs shall be encapsulated into a RS codeword of fixed length. The last RS codeword will be shortened in the case where the number of remaining MAC PDUs is less than four. Or each AT can transmit a concatenation of several bursts, where each of these burst will transmit only one FEC block containing up to 4 MAC PDU.

As the AT finishes transmitting its data, it shall ramp down its transmitter. This period of time is expected to overlap a ramp up period of the next AT scheduled for transmission.

#### 5.3.4.1.2 TDD Case

##### 5.3.4.1.2.1 Downlink

The TDD downlink is similar to the FDD downlink with some differences:

- No TDMA zone is required, as inherently all ATs are half-duplex and no special handling is required.
- The actual downlink frame length is less than 1 ms as only a portion of the full frame is allocated for downlink means (see figure 31). The UL transmissions starting time within a frame is determined by the UL Map.
- At the end of the TDD downlink frame a Rx/Tx switching time of at least 48 channel symbols corresponding to about 2 µs is required for the AT for switching from the PHY reception to the PHYtransmission mode.

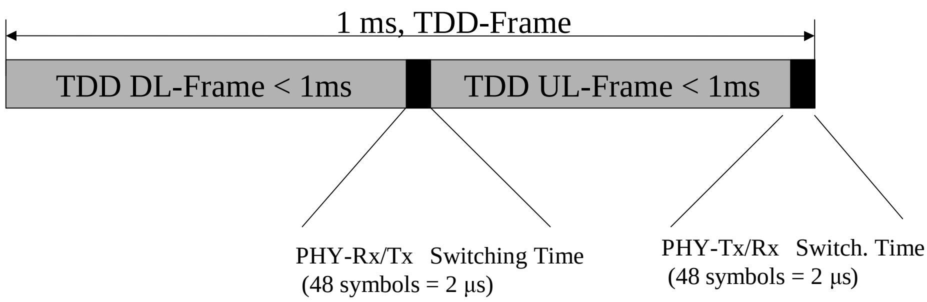



**Figure 31: TDD frame structure**

##### 5.3.4.1.2.2 Uplink

The TDD uplink is similar to the FDD uplink with some differences:

- The actual uplink frame length is less than 1 ms as only a portion of the full frame is allocated for uplink means (see figure 31).
- At the end of the TDD uplink frame a Tx/Rx switching time of at least 48 channel symbols corresponding to about 2 µs is required for the AT for switching from the PHY transmission to the PHY reception mode.

### 5.3.4.2 Downlink TDMA-burst for optional TDMA zone

The structure of the bursts in the TDMA zone of the downlink channel shall be the following:


**Figure 32: Downlink TDMA burst structure**

- PREAMBLE: A fixed length 16 symbols preamble, based on a 2 X 8 symbol CAZAC sequences, which shall be transmitted with the same average power as the modulated data symbols.
- Data or payload Symbols: An integer number of MAC- PDUs of Payload from DLC layer, scrambled and FEC encoded, which shall be transmitted with the relevant PHY mode and which will have variable length according to the relevant PHY mode.

The Data symbols shall be composed of one or more FEC blocks. Every FEC block shall contain 4 MAC PDUs, only the last FEC block in a PHY burst shall contain a number of MAC PDUs equal to 1, 2, 3 or 4 in order to complete the transmission of the number of MAC PDUs foreseen for the burst.

The number of symbols within each FEC block depends on the relevant PHY mode, according to table 12.

The total length of a burst shall be an integer number of symbols, therefore, the last symbol shall be padded with bit values = 0 as necessary.

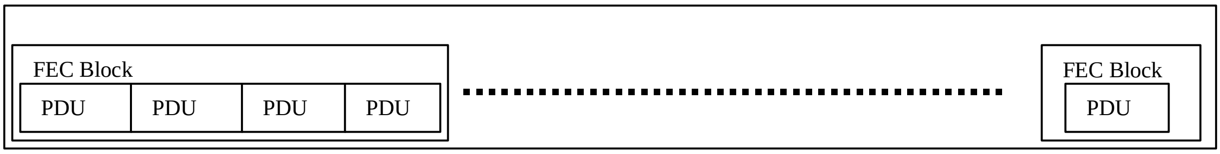



**Figure 33: Downlink TDMA payload structure**

**Table 12: Number of modulated symbols per downlink FEC block**

| PHY mode | PDU/ FEC block | Bytes/ PDU | RS Bytes/ FEC block | CC bits/ FEC block | No. of padding bits | TOTAL symbols/FEC block |
|---|---|---|---|---|---|---|
| 4QAM, RS+CC2/3 | 4 | 54 | 16 | 931 | 1 | 1 397 |
| 4QAM, RS | 4 | 54 | 16 | 0 | 0 | 928 |
| 16QAM, RS+CC7/8 | 4 | 54 | 16 | 266 | 0 | 532 |
| 16QAM, RS | 4 | 54 | 16 | 0 | 0 | 464 |
| 64QAM, RS+CC5/6 | 4 | 54 | 16 | 376 | 0 | 373 |
| 64QAM, RS | 4 | 54 | 16 | 0 | 4 | 310 |
| **PHY mode** | **PDU/ FEC block** | **Bytes/ PDU** | **RS bytes/ FEC block** | **CC bits/ FEC block** | **No. of padding bits** | **TOTAL symbols/FEC block** |
| 4QAM, RS+CC2/3 | 3 | 54 | 16 | 715 | 1 | 1 073 |
| 4QAM, RS | 3 | 54 | 16 | 0 | 0 | 712 |
| 16QAM, RS+CC7/8 | 3 | 54 | 16 | 210 | 0 | 410 |
| 16QAM, RS | 3 | 54 | 16 | 0 | 0 | 356 |
| 64QAM, RS+CC5/6 | 3 | 54 | 16 | 286 | 0 | 286 |
| 64QAM, RS | 3 | 54 | 16 | 0 | 4 | 238 |
| **PHY mode** | **PDU/ FEC block** | **Bytes/ PDU** | **RS bytes/ FEC block** | **CC bits/ FEC block** | **No. of padding bits** | **TOTAL symbols/FEC block** |
| 4QAM, RS+CC2/3 | 2 | 54 | 16 | 499 | 1 | 749 |
| 4QAM, RS | 2 | 54 | 16 | 0 | 0 | 496 |
| 16QAM, RS+CC7/8 | 2 | 54 | 16 | 146 | 0 | 286 |
| 16QAM, RS | 2 | 54 | 16 | 0 | 0 | 248 |
| 64QAM, RS+CC5/6 | 2 | 54 | 16 | 202 | 0 | 200 |
| 64QAM, RS | 2 | 54 | 16 | 0 | 4 | 166 |
| **PHY mode** | **PDU/ FEC block** | **Bytes/ PDU** | **RS bytes/ FEC block** | **CC bits/ FEC block** | **No. of padding bits** | **TOTAL symbols/FEC block** |
| 4QAM, RS+CC2/3 | 1 | 54 | 16 | 283 | 1 | 425 |
| 4QAM, RS | 1 | 54 | 16 | 0 | 0 | 280 |
| 16QAM, RS+CC7/8 | 1 | 54 | 16 | 82 | 0 | 162 |
| 16QAM, RS | 1 | 54 | 16 | 0 | 0 | 140 |
| 64QAM, RS+CC5/6 | 1 | 54 | 16 | 118 | 0 | 114 |
| 64QAM, RS | 1 | 54 | 16 | 0 | 4 | 94 |
| NOTE: In case if the convolutional coding is used, for each FEC block 6 tailbits shall be considered as well. | | | | | | |

### 5.3.4.3 Uplink burst

Three different types of bursts shall be implemented in the uplink channel.

#### 5.3.4.3.1 Long burst (data or signalling)

The long burst can be used for data, signalling or dummy bytes transmission. The UL burst transmission of a given AT shall have one of the following structure:

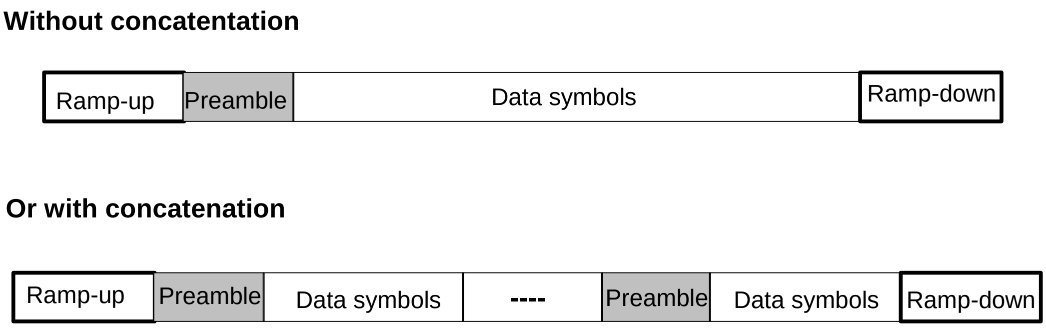



**Figure 34: UL TDMA long burst structure**

where:

- Ramp-up and Ramp-down time, each shall be of fixed length with 8 symbols.
- The UL burst preamble shall consist of 16 or 32 symbols, which shall be a repetition of 8 or 16 CAZAC sequences, which shall be transmitted using the four corner points of the modulation constellation (maximum power).
- Data or payload Symbols: An integer number of MAC PDUs, scrambled and FEC encoded, which shall be transmitted with the relevant PHY mode and which will have variable length according to the relevant PHY mode.

The Data symbols will be composed of one or more FEC blocks, where each FEC block may contain up to 4 MAC PDUs.

Two possibilities may exist for each AT for UL burst transmission (see figure 34):

- **AT-without burst concatenation:** Each AT transmits an UL burst, made of a ramp-up time, UL preamble and several FEC-blocks.
- **With burst-concatenation:** Each AT transmits a concatenation of several bursts, where each one carries one FEC block containing 4 MAC PDUs (except the last burst that shall carry 1 to 4 MAC PDUs). The Ramp-up time shall be used only at the beginning of the first burst, i.e. the ramp-up time shall be excluded between two consecutive bursts.

The burst concatenation is optional for the APT and mandatory for AT. Burst concatenation will be active on a carrier basis. The APT will broadcast the supported UL burst transmission by a relevant field in the control zone.

The number of symbols within each FEC block depends on the relevant PHY mode, according to table 13 for mandatory FEC and corresponding parameters for optional FEC is given in table 14.

The total length of a burst shall be an integer number of channel symbols, therefore, the last channel symbol shall be padded with bit values = 0 as necessary.

**Table 13: Number of modulated symbols per UL mandatory FEC block**

| PHY mode | PDU/ FEC block | Bytes /PDU | RS bytes/ FEC block | CC bits/ FEC block | No of padding bits | TOTAL symbols/FEC block |
|---|---|---|---|---|---|---|
| 4QAM,RS+CC2/3 | 4 | 55 | 16 | 947 | 1 | 1 421 |
| 4QAM, RS | 4 | 55 | 16 | 0 | 0 | 944 |
| 16QAM, RS+CC7/8 | 4 | 55 | 16 | 274 | 0 | 542 |
| 16QAM, RS | 4 | 55 | 16 | 0 | 0 | 472 |
| **PHY mode** | **PDU/ FEC block** | **Bytes /PDU** | **RS bytes/ FEC block** | **CC bits/ FEC block** | **CC bits/ FEC block** | **TOTAL symbols/FEC block** |
| 4QAM,RS+CC2/3 | 3 | 55 | 16 | 727 | 1 | 1 091 |
| 4QAM, RS | 3 | 55 | 16 | 0 | 0 | 724 |
| 16QAM, RS+CC7/8 | 3 | 55 | 16 | 210 | 0 | 416 |
| 16QAM, RS | 3 | 55 | 16 | 0 | 0 | 362 |
| **PHY mode** | **PDU/ FEC block** | **Bytes /PDU** | **RS bytes/ FEC block** | **CC bits/ FEC block** | **CC bits/ FEC block** | **TOTAL symbols/FEC block** |
| 4QAM,RS+CC2/3 | 2 | 55 | 16 | 507 | 1 | 761 |
| 4QAM, RS | 2 | 55 | 16 | 0 | 0 | 504 |
| 16QAM, RS+CC7/8 | 2 | 55 | 16 | 146 | 0 | 290 |
| 16QAM, RS | 2 | 55 | 16 | 0 | 0 | 252 |
| **PHY mode** | **PDU/ FEC block** | **Bytes /PDU** | **RS bytes/ FEC block** | **CC bits/ FEC block** | **CC bits/ FEC block** | **TOTAL symbols/FEC block** |
| 4QAM,RS+CC2/3 | 1 | 55 | 16 | 287 | 1 | 431 |
| 4QAM, RS | 1 | 55 | 16 | 0 | 0 | 284 |
| 16QAM, RS+CC7/8 | 1 | 55 | 16 | 82 | 0 | 164 |
| 16QAM, RS | 1 | 55 | 16 | 0 | 0 | 142 |
| NOTE: In case if the convolutional coding is used, for each FEC block 6 tailbits shall be considered as well. | | | | | | |

The TPC parameters depend on the PHY mode and the FEC block size. The TPC parameters for the uplink transmission are given in table 14.

**Table 14: Optional TPC parameters for the uplink PHY modes**

| Equivalent mandatory PHY mode | PDU/ FEC block | Bytes/PD U | Turbo Product Code (see note 1) | Shortening (see note 2) | Number of padding bits |
|---|---|---|---|---|---|
| 4QAM, RS+CC2/3 | 4 | 55 | (64,51)(64,57) | 12 X 11 X 16 | 101 |
| 4QAM, RS | 4 | 55 | (64,63)(64,63) | 19 X 22 X 20 | 16 |
| 16QAM, RS+CC7/8 | 4 | 55 | (64,57)(64,63)+ | 0 X 31 X 40 | 26 |
| 16QAM, RS | 4 | 55 | (64,63)(64,63) | 19 X 22 X 20 | 16 |
| **Equivalent mandatory PHY mode** | **PDU/ FEC block** | **Bytes/PD U** | **Turbo Product Code (see note 1)** | **Shortening (see note 2)** | **Number of padding bits** |
| 4QAM, RS+CC2/3 | 3 | 55 | (64,51)(64,57) | 30 X 0 X 33 | 38 |
| 4QAM, RS | 3 | 55 | (64,63)(64,63)+ | 30 X 23 X 0 | 13 |
| 16QAM, RS+CC7/8 | 3 | 55 | (64,57)(32,31) | 13 X 0 X 20 | 20 |
| 16QAM, RS | 3 | 55 | (64,63)(64,63)+ | 30 X 23 X 0 | 13 |
| **Equivalent mandatory PHY mode** | **PDU/ FEC block** | **Bytes/PD U** | **Turbo Product Code (see note 1)** | **Shortening (see note 2)** | **Number of padding bits** |
| 4QAM, RS+CC2/3 | 2 | 55 | (64,51)(32,26) | 7 X 3 X 8 | 4 |
| 4QAM, RS | 2 | 55 | (64,63)(32,31)+ | 9 X 23 X 0 | 24 |
| 16QAM, RS+CC7/8 | 2 | 55 | (64,63)(32,31)+ | 22 X 6 X 21 | 39 |
| 16QAM, RS | 2 | 55 | (64,63)(32,31)+ | 9 X 23 X 0 | 24 |
| **Equivalent mandatory PHY mode** | **PDU/ FEC block** | **Bytes/PD U** | **Turbo Product Code (see note 1)** | **Shortening (see note 2)** | **Number of padding bits** |
| 4QAM, RS+CC2/3 | 1 | 55 | (64,51)(16,11) | 0 X 11 X 0 | 13 |
| 4QAM, RS | 1 | 55 | (64,57)(16,15) | 4 X 17 X 0 | 4 |
| 16QAM, RS+CC7/8 | 1 | 55 | (32,26)(32,31)+ | 9 X 6 X 0 | 32 |
| 16QAM, RS | 1 | 55 | (64,57)(16,15) | 4 X 17 X 0 | 4 |
| NOTE 1: The first code is the row code (N_R, K_R), the second is the column code (N_C, K_C). The plus (+) indicates that the hyper codes additional line is used.<br>NOTE 2: In the order: Sx X Sy X Sb. | | | | | |

#### 5.3.4.3.2 Short signalling burst

The structure of the short signalling bursts in the uplink channel shall be the following:


**Figure 35: UL TDMA short burst structure**

Ramp-up and Ramp-down time, each shall be of fixed length with 8 symbols.

- The UL short burst preamble shall consist of 16 or 32 symbols, which shall be a repetition of 8 or 16 CAZAC sequences, which shall be transmitted using the four corner points of the modulation constellation (maximum power).
- Data symbols: A fixed number of symbols from DLC layer, scrambled and FEC encoded, which shall be transmitted with the assigned PHY mode. The data symbols shall carry only one short signalling MAC PDU, i.e. one FEC block.

#### 5.3.4.3.3 Ranging burst

The structure of the ranging bursts for first initialization in the uplink channel shall be the following:

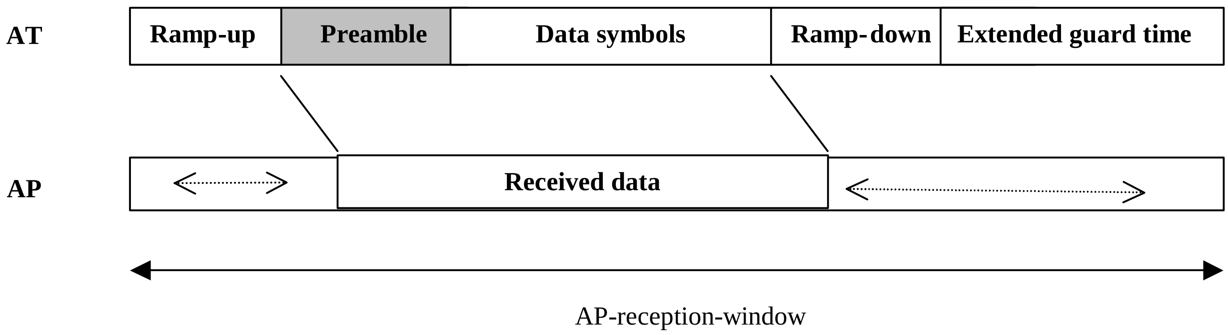



**Figure 36: UL TDMA ranging burst structure**

For the AT, the data shall be transmitted at the beginning of the burst. The format of the burst within the window shall comply with the format of a short signalling burst with an extended guard time, and may be received anywhere within the AP-Rx Window (depending on the position of the AT within the sector). The AP measures the delay and through the ATTC messages (see later), the AT corrects its transmission time.

The preamble length for this burst shall be 32 symbols, made of 2 X 16 CAZAC sequences, where the same CAZAC-sequence as the UL TDMA long burst shall be used.

The length of the extended guard time is between 20 µs and 80 µs. The exact figure of the extended guard time depends on the deployment scenario (cell size) where this figure shall be provided by the NMS.

### 5.3.4.4 Preambles structure

#### 5.3.4.4.1 DL frame preamble

The DL frame preamble shall have a length of 32 symbols, which shall be a repetition of 16 symbols CAZAC sequence, where the original CAZAC sequence shall have the following preamble structure:

**1 1 j -1 j -j j 1 -1 -1 j -1 -j j j 1** 1 1 j -1 j -j j 1 -1 -1 j -1 -j j j 1

After π/4 rotation, the transmitted CAZAC sequence with complex symbols shall have the following structure:

**Table 15: DL frame CAZAC sequence**

| No | Original seq. | I | Q |
|---|---|---|---|
| 1 | 1 | 1/√2 | 1/√2 |
| 2 | 1 | 1/√2 | 1/√2 |
| 3 | j | -1/√2 | 1/√2 |
| 4 | -1 | -1/√2 | -1/√2 |
| 5 | j | -1/√2 | 1/√2 |
| 6 | -j | 1/√2 | -1/√2 |
| 7 | j | -1/√2 | 1/√2 |
| 8 | 1 | 1/√2 | 1/√2 |
| 9 | -1 | -1/√2 | -1/√2 |
| 10 | -1 | -1/√2 | -1/√2 |
| 11 | j | -1/√2 | 1/√2 |
| 12 | -1 | -1/√2 | -1/√2 |
| 13 | -j | 1/√2 | -1/√2 |
| 14 | j | -1/√2 | 1/√2 |
| 15 | j | -1/√2 | 1/√2 |
| 16 | 1 | 1/√2 | 1/√2 |

### 5.3.4.4.2 DL TDMA burst preamble

The DL TDMA preamble shall have a length of 16 symbols, which shall be a repetition of 8 symbols CAZAC sequence, where the original CAZAC sequence shall have the following preamble structure:

**-1 j -1 1 1 j 1 1** -1 j -1 1 1 j 1 1

After π/4 rotation, the transmitted CAZAC sequence with complex symbols shall have the following structure:

**Table 16: DL TDMA burst CAZAC sequence**

| No | Original seq. | I | Q |
|---|---|---|---|
| 1 | -1 | -1/√2 | -1/√2 |
| 2 | j | -1/√2 | 1/√2 |
| 3 | -1 | -1/√2 | -1/√2 |
| 4 | 1 | 1/√2 | 1/√2 |
| 5 | 1 | 1/√2 | 1/√2 |
| 6 | j | -1/√2 | 1/√2 |
| 7 | 1 | 1/√2 | 1/√2 |
| 8 | 1 | 1/√2 | 1/√2 |

### 5.3.4.4.3 UL TDMA burst preamble

The UL TDMA preamble shall have a length of 16 or 32 symbols, which shall be a repetition of 8 or 16 CAZAC sequences, respectively.

The AT shall be able to generate both preamble sequences. The AP shall be able to receive at least one of these preamble sequences. The AP shall decide which of these preamble sequences shall be transmitted by the AT. In the case where the AP receives/demodulates both preamble sequences, the selection of these preamble sequences could be done per AT basis.

**Case 16-symbols preamble** (twice repeated 8 symbols CAZAC sequence) with original sequence:

**1 -1 j 1 1 1 j -1** 1 -1 j 1 1 1 j -1

After π/4 rotation, the transmitted CAZAC sequence with complex symbols shall have the following structure:

**Table 17: UL TDMA burst CAZAC sequence, case 16 symbols preamble**

| No | Original seq. | I | Q |
|---|---|---|---|
| 1 | 1 | 1/√2 | 1/√2 |
| 2 | -1 | -1/√2 | -1/√2 |
| 3 | j | -1/√2 | 1/√2 |
| 4 | 1 | 1/√2 | 1/√2 |
| 5 | 1 | 1/√2 | 1/√2 |
| 6 | 1 | 1/√2 | 1/√2 |
| 7 | j | -1/√2 | 1/√2 |
| 8 | -1 | -1/√2 | -1/√2 |

**Case 32-symbols preamble** (twice repeated 16 symbols CAZAC sequence) with original sequence:

**j, -1, 1, 1, -1, 1, -j, 1, -j, -1, -1, 1, 1, 1, j, 1** j, -1, 1, 1, -1, 1, -j, 1, -j, -1, -1, 1, 1, 1, j, 1

After π/4 rotation, the transmitted CAZAC sequence with complex symbols will have the following structure:

**Table 18: UL TDMA burst CAZAC sequence, case 32 symbols**

| No | Original seq. | I | Q |
|---|---|---|---|
| 1 | j | -1/√2 | -1/√2 |
| 2 | -1 | -1/√2 | -1/√2 |
| 3 | 1 | 1/√2 | 1/√2 |
| 4 | 1 | 1/√2 | 1/√2 |
| 5 | -1 | -1/√2 | -1/√2 |
| 6 | 1 | 1/√2 | 1/√2 |
| 7 | -j | 1/√2 | -1/√2 |
| 8 | 1 | 1/√2 | 1/√2 |
| 9 | -j | 1/√2 | -1/√2 |
| 10 | -1 | -1/√2 | -1/√2 |
| 11 | -1 | -1/√2 | -1/√2 |
| 12 | 1 | 1/√2 | 1/√2 |
| 13 | 1 | 1/√2 | 1/√2 |
| 14 | 1 | 1/√2 | 1/√2 |
| 15 | j | -1/√2 | 1/√2 |
| 16 | 1 | 1/√2 | 1/√2 |

## 5.3.5 Pulse shaping and wave forming

### 5.3.5.1 Pulse shaping

An appropriate spectrum shaping at transmitter output is foreseen in HIPERACCESS, in order to obtain a band-limited signal waveform, then fulfilling existing spectrum emission requirements [2], [3].

For this purpose, a raised cosine filtering shall be implemented.

The raised cosine filter shall have equal splitting between Tx and Rx side; e.g. a Square-Root Raised Cosine (SRRC) filter shall be included in Tx chain.

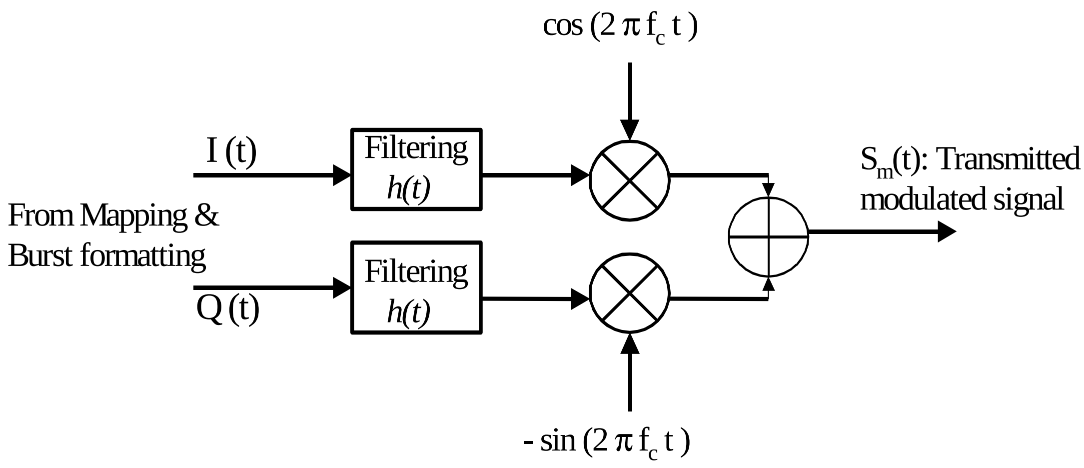



**Figure 37: Filtering and wave forming**

The theoretical transfer function for a SRRC filter is reported in the following equation:

$$H(f)=\begin{cases} 1 & \text{for } |f|< f_N(1-\alpha) \\ \left\{\frac{1}{2}+\frac{1}{2}\sin\frac{\pi}{2f_N}\left[\frac{f_N-|f|}{\alpha}\right]\right\}^{1/2} & \text{for } f_N(1-\alpha)\le |f| \le f_N(1+\alpha) \\ 0 & \text{for } |f|> f_N(1+\alpha) \end{cases}$$

**where** $f_N=\frac{1}{2T_s}$ **is the Nyquist frequency.**

The raised cosine filter *roll-off* factor $\alpha$ - e.g. the filter *excess bandwidth* - shall be equal to **0,25**.

### 5.3.5.2 Wave forming

The modulated waveform transmitted shall be compliant to the following equation:

$$s_m(t)=\{I(t)*h(t)\}\cos(2\pi f_c t)-\{Q(t)*h(t)\}\sin(2\pi f_c t)$$

where, in this formula *h(t)* represents the inverse Fourier transform of *H(f)* as described in clause 5.3.5.1 and I + jQ is the normalized complex $2^M$ QAM symbol coming out from symbol mapping function, as described in clauses 5.3.3 and 5.3.4.4, where * represents the convolution operation and $f_c$ is the carrier frequency. A practical implementation may include some intermediate frequency conversion steps, which may lead to some spectrum inversion, yet the end result should satisfy the above formula (e.g. without spectrum inversion).

# 5.4 Adaptive coding and modulation

## 5.4.1 General

For mandatory FEC scheme, by puncturing the inner code rate for a given modulation scheme, large number of combinations of coding and modulation would be possible. However, among all these combinations, two different sets of PHY modes shall be used: One mandatory and one optional, where each set of PHY modes can be applied in an adaptive way for both UL and DL (see later). It should be noticed that the algorithms for the selection of a given PHY mode will not be specified.

In order to guarantee the interoperability, the following rules/procedures should be applied:

- The indication of the PHY mode shall be done on a burst-by-burst basis and the adaptation shall be done on a frame-by-frame basis.
- Each AT shall measure the C/N and the Rx-power and communicate these values to the AP. Furthermore, each AT shall be able to communicate the available *Tx power margin reverse* as well to the AP. Then, following these parameters the AP centrally decides to change the uplink PHY mode or not.
- For the UL a minimum amount of traffic must be ensured in order for the AP to be able to continuously measure the C/N ratio with a given accuracy.
- HA shall use one mandatory and one optional predefined set of PHY modes. The first set of PHY modes shall be supported by the AT and AP; where the second set shall be mandatory for AT and optional for AP.
- Out of these sets of PHY modes, only one set of PHY modes shall be used per sector. The choice of the set of PHY modes could be determined by the Network Management System (NMS).

### 5.4.2 Downlink PHY modes

Two sets of PHY modes (Set-1 to Set-2) are specified for the downlink (see table 19). The reason for specifying different sets of PHY modes is to offer a higher flexibility for the HA standard deployment, where the adequate choice of a given set of PHY modes will be determined by the deployment scenario: coverage, interference, rain zone, etc. The first set shall be used for dense cellular system and the second set can be used for isolated cells to achieve a higher capacity.

**Table 19: DL PHY modes characteristics**

| Set of Downlink PHY modes | Inner code | Outer code (K = 1 to 4 MAC PDUs) | Modulation |
|---|---|---|---|
| **Set-1, Mandatory** | | | |
| **Mode-1** | CC2/3 | RS (K, K + 16, t=8) | 4QAM |
| **Mode-2** | no | RS (K, K + 16, t=8) | 4QAM |
| **Mode-3** | CC7/8 | RS (K, K + 16, t=8) | 16QAM |
| **Mode-4 (optional)** | CC5/6 | RS (K, K + 16, t=8) | 64QAM |
| **Set-2, Optional** | | | |
| **Mode-1** | CC2/3 | RS (K, K + 16, t=8) | 4QAM |
| **Mode-2** | no | RS (K, K + 16, t=8) | 4QAM |
| **Mode-3** | no | RS (K, K + 16, t=8) | 16QAM |
| **Mode-4 (optional)** | no | RS (K, K + 16, t=8) | 64QAM |

As shown in figures 28 and 29, for the downlink, except the end of the TDM- or TDMA-zone corresponding to a given PHY mode, 4 long MAC PDUs shall be mapped to the outer RS codeword, where at the end of the TDM- or TDMA-zone smaller number of MAC PDUs (≤ 4) per RS codeword shall be transmitted. This strategy offers a high throughput for the downlink.

The reception of both Sets by the AT is mandatory.

The channel coding and modulation parameters shall be adapted in a *frame-by-frame* basis. Therefore, the number of channel symbols for each FEC block will depend on the modulation, inner and outer code rates. In the presence of inner code, the number of channel symbols per FEC block is given by: $\{[(K + 16) X 8 + 6_{Tailbits}] / r + padding\} / M$; where r is the inner code rate, M is number of bits per modulated symbol and K is the number of information bytes per Reed-Solomon codeword.

### 5.4.3 Uplink PHY modes

Two sets of PHY modes (Set-1 to Set-2), being the subsets of the downlink modes, are specified as mandatory for the uplink (see table 20). The choice of a given set of PHY mode shall be determined by the network deployment scenario.

**Table 20: UL PHY modes characteristics for mandatory FEC**

| Sets of Uplink PHY modes | Inner code | Outer code (K = 1 to 4 MAC PDUs) | Modulation |
|---|---|---|---|
| **Set-1** | | | |
| **Mode-1** | CC2/3 | RS (K, K + 16, t=8) | 4QAM |
| **Mode-2** | no | RS (K, K + 16, t=8) | 4QAM |
| **Mode-3 (optional)** | CC7/8 | RS (K, K + 16, t=8) | 16QAM |
| **Set-2** | | | |
| **Mode-1** | CC2/3 | RS (K, K + 16, t=8) | 4QAM |
| **Mode-2** | no | RS (K, K + 16, t=8) | 4QAM |
| **Mode-3 (optional)** | no | RS (K, K + 16, t=8) | 16QAM |

The channel coding and modulation parameters for the uplink (see figure 30) are adapted in a *burst-by-burst* or *sector-by-sector* basis. Therefore, the number of channel symbols for each FEC-block will depend on the modulation, inner and outer code rates. In the presence of inner code, the number of channel symbols per FEC-block is given by: $\{[(K + 16) \times 8 + 6_{\text{Tailbits}}] / r + \text{padding}\} / M$; where r is the inner code rate, M is the number of bits per modulated symbol and K is the number of information bytes per Reed-Solomon codeword.

It shall be mentioned that the reception of Set-1 by the AP is mandatory, but the reception of Set-2 is optional for AP.

In table 21, the UL PHY mode characteristics in case of optional TPC are given.

**Table 21: UL PHY modes parameters for optional FEC**

| PHY modes for Set-1 and Set-2 | PDU/ FEC block | Bytes/PDU | Turbo Product Code (see note 1) | Shortening (see note 2) | Number of padding bits |
|---|---|---|---|---|---|
| Mode-1 (set 1 and 2) | 4 | 55 | (64,51)(64,57) | 12 X 11 X 16 | 101 |
| Mode-2 (set 1 and 2) | 4 | 55 | (64,63)(64,63) | 19 X 22 X 20 | 16 |
| Mode-3 (set 1) | 4 | 55 | (64,57)(64,63)+ | 0 X 31 X 40 | 26 |
| Mode-3 (set 2) | 4 | 55 | (64,63)(64,63) | 19 X 22 X 20 | 16 |
| **PHY modes for Set-1 and Set-2** | **PDU/ FEC block** | **Bytes/PDU** | **Turbo Product Code (see note 1)** | **Shortening (see note 2)** | **Number of padding bits** |
| Mode-1 (set 1 and 2) | 3 | 55 | (64,51)(64,57) | 30 X 0 X 33 | 38 |
| Mode-2 (set 1 and 2) | 3 | 55 | (64,63)(64,63)+ | 30 X 23 X 0 | 13 |
| Mode-3 (set 1) | 3 | 55 | (64,57)(32,31) | 13 X 0 X 20 | 20 |
| Mode-3 (set 2) | 3 | 55 | (64,63)(64,63)+ | 30 X 23 X 0 | 13 |
| **PHY modes for Set-1 and Set-2** | **PDU/ FEC block** | **Bytes/PDU** | **Turbo Product Code (see note 1)** | **Shortening (see note 2)** | **Number of padding bits** |
| Mode-1 (set 1 and 2) | 2 | 55 | (64,51)(32,26) | 7 X 3 X 8 | 4 |
| Mode-2 (set 1 and 2) | 2 | 55 | (64,63)(32,31)+ | 9 X 23 X 0 | 24 |
| Mode-3 (set 1) | 2 | 55 | (64,63)(32,31)+ | 22 X 6 X 21 | 39 |
| Mode-3 (set 2) | 2 | 55 | (64,63)(32,31)+ | 9 X 23 X 0 | 24 |
| **PHY modes for Set-1 and Set-2** | **PDU/ FEC block** | **Bytes/PDU** | **Turbo Product Code (see note 1)** | **Shortening (see note 2)** | **Number of padding bits** |
| Mode-1 (set 1 and 2) | 1 | 55 | (64,51)(16,11) | 0 X 11 X 0 | 13 |
| Mode-2 (set 1 and 2) | 1 | 55 | (64,57)(16,15) | 4 X 17 X 0 | 4 |
| Mode-3 (set 1) | 1 | 55 | (32,26)(32,31)+ | 9 X 6 X 0 | 32 |
| Mode-3 (set 2) | 1 | 55 | (64,57)(16,15) | 4 X 17 X 0 | 4 |
| NOTE 1: The first code is the row code (N_R, K_R), the second is the column code (N_C, K_C). The plus (+) indicates that the hyper codes additional line is used.<br>NOTE 2: In the order : Sx X Sy X Sb. | | | | | |

## 5.4.4 Means for UL and DL PHY modes adaptation

The choice of a given used PHY mode, i.e. coding and modulation parameters combination will depend on the link quality between the AP and the AT in both directions. If there is a need for changing the used parameters, the DLC-layer should decide on the change for the next frame of the PHY mode, independently for each uplink and downlink direction.

The exact algorithm for the PHY mode change process is out of the scope of the standardization process. The standard will not dictate a specific scenario nor force a specific implementation. Therefore, the AP shall centrally perform all PHY mode change mechanisms.

Even if the specification of PHY mode algorithm details is outside the scope of current TS, some basic aspects need to be addressed here, in order to guarantee minimum performances and interoperability for equipment coming from different vendors.

For change of UL PHY mode (or UL power control, see clause 5.5.3.5.3) and in order to be independent of a given algorithm, the following rules shall be applied:

- For the UL, the AP shall grant a minimum amount of traffic of at least 200 channel symbols per burst in every time interval 50 ms to 200 ms in order to ensure a continuous measurement of the C/N and receiver power in the AP with a given accuracy.
- Measurement of Carrier to Noise ratio (C/N) in the AP shall be measured with an accuracy of ±1 dB over the range 5 dBto 30 dB and with a measurement interval time of 50 ms to 200 ms. The measured C/N shall have a resolution of 0,25 dB.
- Measurement of the received power in the AP, shall be measured with an accuracy of ±1 dB (relative measurement accuracy). Absolute received power measurement shall have an accuracy of ±3 dB and with a measurement interval time of 50 ms to 200 ms. The measured received power shall have a resolution of 0,25 dB.
- Instantaneous transmitted *Tx power margin reserve* in the AT, measured with an accuracy of ± 2 dB for the top 12 dB of the dynamic range and with a measurement interval time of 50 ms. The *Tx power margin reserve* shall have a resolution of 0,25 dB. The transmitted *power margin reserve* is the difference between the actual transmitted power and the maximum transmitted power of the AT. If the actual transmitted power shall be also transmitted, e.g. for performance monitoring purposes, it shall have a resolution of 1 dB.
- Each AT shall be able to communicate to the AP, its instantaneous transmitted power margin within an interval time 50 ms to 200 ms.
- Based on these measured parameters: C/N at AP, Rx Power in AP and the instantaneous Tx power margin in the AT, the AP can decide for the change of UL PHY mode or performing UL power control (see clause 5.5.3.5.3).

For change of DL PHY mode and in order to be independent of a given algorithm, the following rules shall be applied:

- Measurement of the Carrier to Noise ratio (C/N) in the AT, shall be measured with an accuracy of ±1 dB over the range 5 dB to 30 dB and with a measurement interval time of 50 ms. The measured C/N shall have a resolution of 0,25 dB.
- Measurement of the received power in the AT, measured with an accuracy of ±1 dB (relative measurement accuracy). Absolute received power measurement shall have an accuracy of ±3 dB and with a measurement interval time of 50 ms. The measured received power shall have a resolution of 0,25 dB.
- Each AT shall be able to communicate to the AP, its measured C/N and received power within an interval time 50 ms to 200 ms.
- Based on these measured parameters: C/N at AT, Rx Power in AT (and the instantaneous power margin in the AP), the AP can decide for the change of DL PHY mode.

The PHY layer shall also provide some additional means to the DLC layer in order to correctly apply these decisions driven by algorithms, as follows:

- Capability (on the AT) to automatically change the transmission power for every PHY mode change.
- Capability (on the AT) to receive from the DLC layer the values of the automatic power changes for every modulation change foreseen on the Uplink (i.e. PHY Mode-1 to PHY Mode-2, PHY Mode-2 to PHY Mode-3, PHY Mode-3 to PHY Mode-2, PHY Mode-2 to PHY Mode-1).

## 5.4.5 DL Control zone protection

The DL control zone will be broadcast at the beginning of each downlink frame (see clause 5.3.4.1) and shall be received by each AT. This information being the most important one, therefore, it should be strongly protected.

The control zone bytes shall be protected with the inner mother code r = 1/2 (without puncturing) and shortened outer Reed-Solomon code RS(46, 30, t=8). The modulation for the control zone bytes shall be 4QAM that allows more than 2 dB more protection comparing to the most protected mode of data signal (4QAM, r = 2/3).

The number of channel symbols for each FEC-block, in table 22. This result in an overall code rate of about 1/3.

**Table 22: Number of modulated symbols per each FEC-block of the DL control zone**

| Control zone-protection | Inner code | Outer code | Number of channel symbols per RS-codeword |
|---|---|---|---|
| 4QAM | CC1/2 | RS (46, 30, t=8) | 374 |

The coding procedure for protecting the control zone is illustrated in figure 38. The control zone byte-sequence shall be segmented into each K = 30 bytes long. Each of these 30 bytes shall be encoded with the outer shortened RS(46, 30, t=8) code. The remaining k bytes which are less than 30 bytes shall be padded with dummy bytes in order to have a constant length codeword, i.e. 30 bytes before RS coding. Each of the RS codeword after parallel/serial conversion and 6 tailbits insertion shall be encoded with CC1/2 and 4QAM modulated.

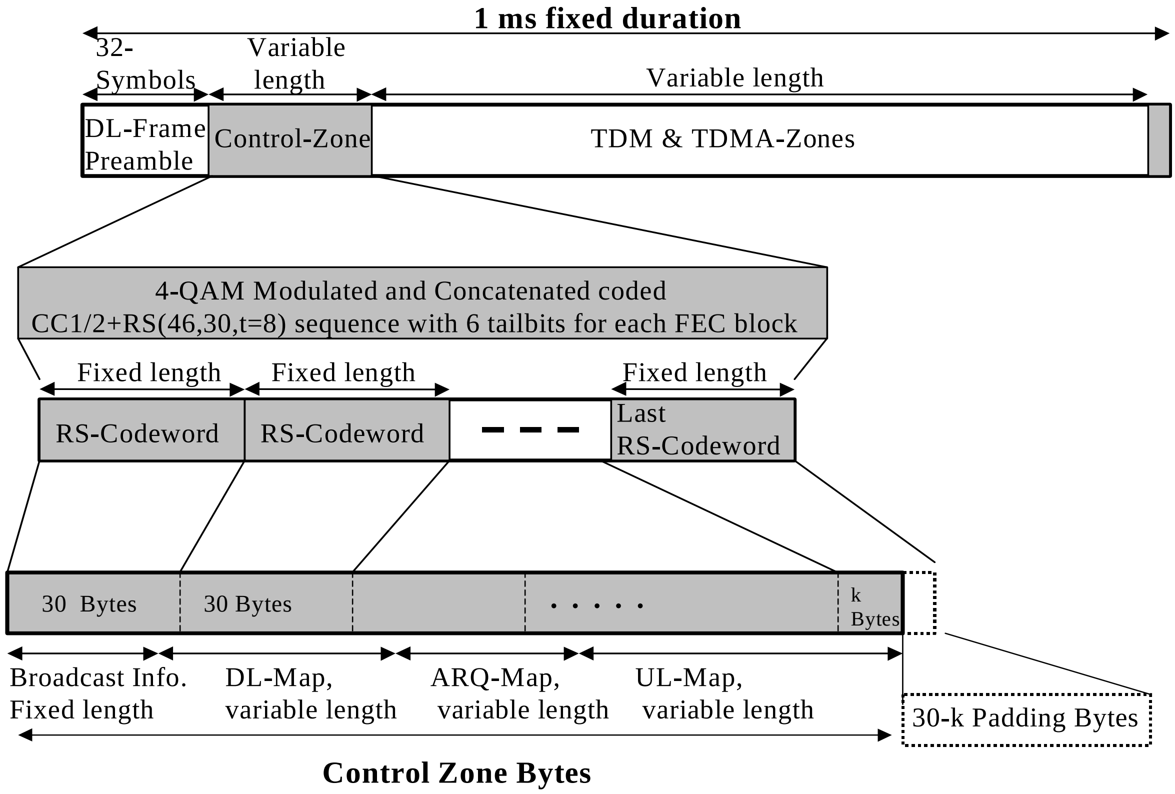



**Figure 38: Coding procedure for control zone**

### 5.4.6 UL short signalling MAC PDU protection

For UL short signalling MAC PDU of 12 bytes length, the same coding scheme as the data shall be used.

**Table 23: UL short signalling PDUs protection modes**

| Sets of UL PHY modes | Inner code | Outer code | Total code rate | No. of padding | Mod. | No of symbols/burst |
|---|---|---|---|---|---|---|
| **Set-1** | | | | | | |
| **Mode-1** | CC2/3 | RS (28, 12, t=8) | 0.28 | 1 | 4QAM | 173 |
| **Mode-2** | no | RS (28, 12, t=8) | 0.43 | 0 | 4QAM | 112 |
| **Mode-3 (optional)** | CC7/8 | RS (28, 12, t=8) | 0.37 | 0 | 16QAM | 66 |
| **Set-2** | | | | | | |
| **Mode-1** | CC2/3 | RS (28, 12, t=8) | 0.28 | 1 | 4QAM | 173 |
| **Mode-2** | no | RS (28, 12, t=8) | 0.43 | 0 | 4QAM | 112 |
| **Mode-3 (optional)** | no | RS (28, 12, t=8) | 0.43 | 0 | 16QAM | 56 |

The main advantage of this scheme is to use the same coding scheme as the data. These coding schemes provide **at least 1 dB higher coding gain** than the data. By the same Tx power as the data, in the absence of collision (or strong interference), these UL signalling PDUs will be received Quasi-Error-Free (QEF).

Under the control of the AP, two possibilities may exist for the choice of appropriate PHY modes for UL signalling PDUs:

- **Use the most robust PHY mode (Mode-1) for all UL short signalling MAC PDUs:** The advantage of this scheme is that it is much robust against all imperfections: Same Rx power, only one type of UL burst and better interference immunity. In addition, it provides a high accurate error detection capability. However, it may consume some extra capacity. Note that for the first initialization, each AT shall employ the most robust PHY mode for initial ranging purposes, i.e. ranging burst: 4QAM2/3 + RS(28, 12, t=8).

- **Except of contention windows use the same PHY mode (all modes) as the data:** The advantage of this scheme is that it could provide a higher throughput. Indeed, in case of high order modulation, i.e. 16QAM, in the presence of interference, it results in a poor performance. Therefore, the throughout-gain achieved with this scheme should be considered before using this possibility.

### 5.4.7 Summary of PHY modes for mandatory FEC scheme

In table 24 a summary of all PHY modes, in case of mandatory FEC-scheme for the protection of data and control bytes are recapitulated.

**Table 24: Summary of all PHY modes for mandatory FEC scheme**

| Modulation | Inner code rate | Outer code structure K = 1 - 4 X 55 for UL K = 1 - 4 X 54 for DL | Protection goal |
|---|---|---|---|
| 4QAM | 1/2 | RS(46,30, t=8) | DL control zone |
| 4QAM | 2/3 | RS(28,12, t=8) | UL short signalling PDU |
| 4QAM | - | RS(28,12, t=8) | UL short signalling PDU |
| 16QAM | 7/8 | RS(28,12, t=8) | UL short signalling PDU |
| 16QAM | - | RS(28,12, t=8) | UL short signalling PDU |
| 4QAM | 2/3 | RS (K + 16, K, t=8) | Uplink and downlink long PDU |
| 4QAM | - | RS (K + 16, K, t=8) | Uplink and downlink long PDU |
| 16QAM | 7/8 | RS (K + 16, K, t=8) | Uplink and downlink long PDU |
| 64QAM | 5/6 | RS (K + 16, K, t=8) | Downlink long PDU |
| 16QAM | - | RS (K + 16, K, t=8) | Uplink and downlink long PDU |
| 64QAM | - | RS (K + 16, K, t=8) | Downlink long PDU |

# 5.5 Radio transmission

## 5.5.1 RF carriers

### 5.5.1.1 Nominal frequency bands

HIPERACCESS is targeted for operation in the following frequency bands identified for Fixed Wireless Access (FWA) service use. Spectrum availability for HIPERACCESS in these bands will depend upon the frequency licensing policy and assignments made in specific countries:

- 40,5 GHz to 41,5 GHz / 41,5 GHz to 43,5 GHz and 40,5 GHz to 42 GHz / 42 GHz to 43,5 GHz. Identified for MWS systems in CEPT/ECC Recommendation 01-04 [14]. Frequency assignment guidance given in CEPT/ECC Recommendation 01-04 [14].
- 38,6GHz to 39,3 GHz / 39,3GHz to 40 GHz.
- 31,8 GHz to 32,6 GHz / 32,6 GHz to 33,4 GHz. Channel arrangement identified in CEPT/ERC Recommendation 01-02 [13].
- 31,0 GHz to 31,3 GHz / 31,5 GHz to 31,8 GHz. Channel arrangement identified in CEPT/ERC Recommendation 01-02 [13].
- 31 GHz to 31,075 GHz / 31,225 GHz to 31,300 GHz.
- 29,10 GHz to 29,25 GHz / 31.075 GHz to 31,225 GHz.
- 27,5 GHz to 28,5 GHz / 28,5 GHz to 29,5 GHz, and 27,5 GHz to 27,925 GHz / 27,925 GHz to 28,35 GHz. Identified as a "preferred" frequency band for FWA in CEPT/ERC Recommendation 13-04 [33]. ERC Recommended channel arrangement given in CEPT/ERC Recommendation T/R 13-02 [9]. CEPT/ERC Recommendation 01-03 [17] provides frequency assignment guidance for FWA.
- 24,5 GHz to 25,5 GHz / 25,5 GHz-26,5 GHz. Identified as a "preferred" frequency band for FWA in CEPT/ERC Recommendation 13-04 [33]. ERC Recommended channel arrangement given in CEPT/ERC Recommendation T/R 13-02 [9]. CEPT/ERC Recommendation 00-05 [18] provides frequency assignment guidance for FWA.
- 24,25 GHz to 24,45 GHz / 25,05 GHz to25,25 GHz.
- and other bands used for FWA, which are not specified in the present document.

### 5.5.1.2 Channel plans

For the frequency bands listed above that have a recommended channel arrangement, it is anticipated that HIPERACCESS will operate in a manner consistent with the centre frequencies identified for 28 MHz channelization.

For the 40,5 GHz to 43,5 GHz band, CEPT/ECC Recommendation 01-04 [14] does not identify a specific channel arrangement. However, paired block assignments are strongly recommended as a means of assigning frequencies in a manner that remains agnostic with regard to duplexing scheme. These blocks are based upon an assignment granularity of 1 MHz and an offset of 1,5 GHz between the upper and lower frequency blocks. Exceptionally, due to spectrum availability constraints, an offset between the blocks of 1 GHz may be imposed in some countries (see also annex F).

In the 40 GHz band block assignments, HIPERACCESS will therefore operate in 28 MHz channels on exact centre frequencies that have been derived considering the regulatory "Block Edge Mask" identified in CEPT/ECC Recommendation 01-04 [14].

| | |
|---|---|
| Channel Width and Separation | 28 MHz |
| Duplex Distance | 1 500 MHz |
| Centre Frequency Setting Resolution | 1 MHz |
| NOTE: Exceptionally the duplex distance is 1 000 MHz where use of the 42,5 GHz to 43,5 GHz part of the band is restricted. | |

Examples of the 40 GHz channel positioning are shown in annex B.

## 5.5.2 Accuracy

### 5.5.2.1 Carrier frequency accuracy

In order to meet more stringent coexistence requirements in place today the transmitted RF centre frequency for both the APT and at each AT shall have an absolute accuracy better than ±10 ppm. The value shall be guaranteed over the complete temperature range and time of operation, i.e. ageing for HA equipment. In order to meet this main requirement, following other requirements have been derived for both APT and AT. The absolute carrier frequency accuracy for the APT shall be better than ±8 ppm. Therefore:

- The carrier frequency accuracy for the APT shall be ±8 ppm.
- The AT shall be locked in frequency to the APT.
- The relative accuracy of the AT shall be ±1 ppm with respect to the APT.

### 5.5.2.2 Symbol Clock- nominal frequency and accuracy

The APT transmit symbol clock nominal frequency is 22,4 MHz (i.e. 22,4 million symbols per second).

The APT transmit clock frequency accuracy in the long-term (1 s to 10 s) shall be better than ±8 ppm over the whole temperature range, excluding the contribution due to ageing.

The AT transmit symbol clock frequency shall be phase-locked to the downlink symbol clock frequency.

The peak-to-peak jitter of the symbol clock during a 2-second measurement time shall be less than 2 % of the nominal symbol clock duration for both the APT and the AT.

The AT shall not send any data till locking condition to the APT transmit symbol frequency has been reached.

## 5.5.3 Transmission power

### 5.5.3.1 Transmitted power at the antenna connector

The RF transmit output power level in this clause is referred to the RF connection to the antenna, for both the APT and the AT (point V' of figure 39).

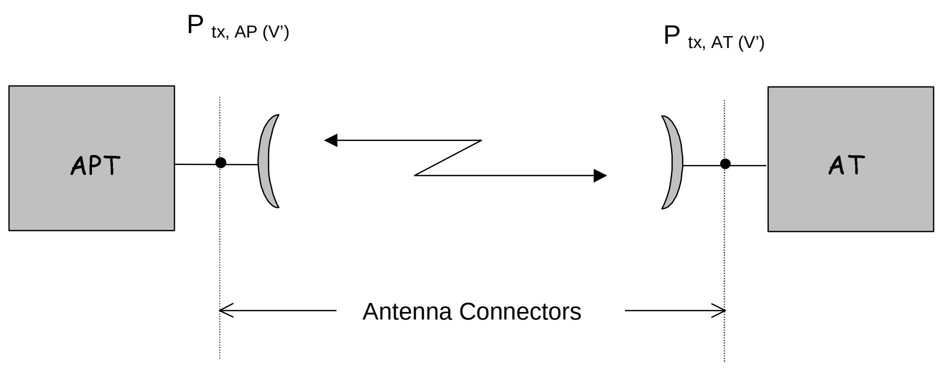



**Figure 39: Radio transmission between the AT and the APT**

### 5.5.3.2 Transmitter maximum output power

**APT**

The APT shall be able to operate with a transmission power at maximum setting of 15 dBm, whatever the PHY mode and radio frequency channel in use.

The transmitted output power accuracy at maximum level shall be better than ±2 dB.

The output power accuracy shall be guaranteed over the complete temperature range of operation for HA equipment.

A capability for limiting *maximum* average output power may be required for regulatory purposes. Here for instance DL power control can be used.

**AT**

- The transmit power at maximum setting in case of QPSK shall be at least 14 dBm.
- The transmit power range at maximum setting in case of 16QAM shall be at least 11 dBm.
- The impact of increasing the power beyond 14 dBm will require the re-evaluation of the parameters for the coexistence and interoperability issue.
- The AT capability of the maximum transmit power during initialization shall be communicated to the AP.
- The resolution of the AT transmit power shall be 1 dB.

The transmitted output power accuracy at maximum level shall be better than ±2 dB.

The output power accuracy shall be guaranteed over the complete temperature range of operation for HA equipment.

### 5.5.3.3 Transmit spectrum mask and adjacent channel performance (NFD)

Transmit parameters shall comply with:

- frequency band 40,5 GHz to 43,5 GHz: EN 301 997-1 [1];
- frequency band 31,8 GHz to 33,4 GHz;
- frequency band 24,25 GHz to 29,5 GHz: EN 301 213-3 [3];
- and all other frequencies.

In the downlink channel the transmitted spectrum shall not exceed the spectrum mask defined by table 25 which specifies more stringent requirements than System Type C spectrum mask defined in EN 301 213-3 [3].

In the uplink channel the transmitted spectrum shall not exceed the spectrum mask defined by table 26 which specifies more stringent requirements than System Type B spectrum mask defined in EN 301 213-3 [3].

Downlink and Uplink spectrum masks are also shown in figure 40 together with EN 301 213-3 masks [3].

**Table 25: Downlink spectrum mask**

| Frequency offset (MHz) | 13 | 14 | 14.4 | 14.8 | 22.4 | 28 | 56 | 70 |
|---|---|---|---|---|---|---|---|---|
| Relative attenuation (dB) | 0 | -15 | -20 | -28 | -34 | -42 | -52 | -52 |

**Table 26: Uplink spectrum mask**

| Frequency offset (MHz) | 11.2 | 13.5 | 14.5 | 22.4 | 28 | 56 | 70 |
|---|---|---|---|---|---|---|---|
| Relative attenuation (dB) | 0 | -7 | -17 | -32 | -37 | -52 | -52 |

The HIPERACCESS Net-Filter-Discriminator (NFD) mask which shall be guaranteed by an HA system, is defined by table 27 for the DL and UL.

**Table 27: Downlink and uplink NFD mask**

| Offset (MHz) | NFD - DL (dB) | NFD - UL (dB) |
|---|---|---|
| 28 | 35,5 | 29 |
| 31,5 | 39 | 34,5 |
| 35 | 42 | 38,5 |
| 38,5 | 45 | 41 |
| 42 | 46,5 | 43 |
| 49 | 49 | 46,5 |
| 56 | 51 | 50 |
| 59,5 | 51,5 | 51 |
| 63 | 52 | 51,5 |
| 70 | 52 | 52 |
| 77 | 52 | 52 |
| 84 | 52 | 52 |

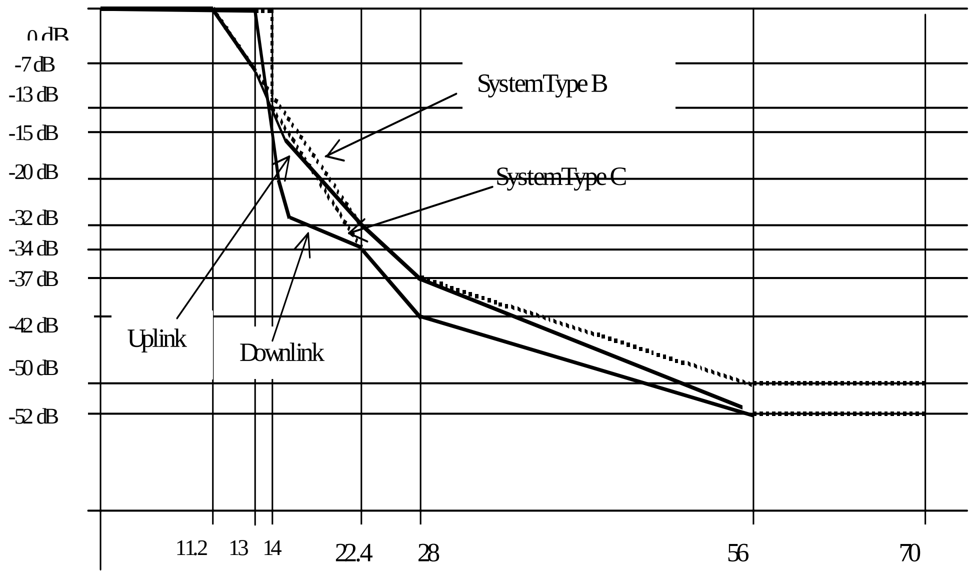



**Figure 40: HA spectrum mask**

In case some continuous wave components exceed the spectrum mask, an additional allowance is given.

In accordance with EN 301 390 [4] and EN 301 213-3 [3], those lines shall:

- be emissions at frequencies which are 250 % of the relevant channel separation outside the nominal carrier frequency;
- not exceed the mask by a factor more than 2,43 dB;
- not be spaced each other in frequency by less than 1,75 MHz.

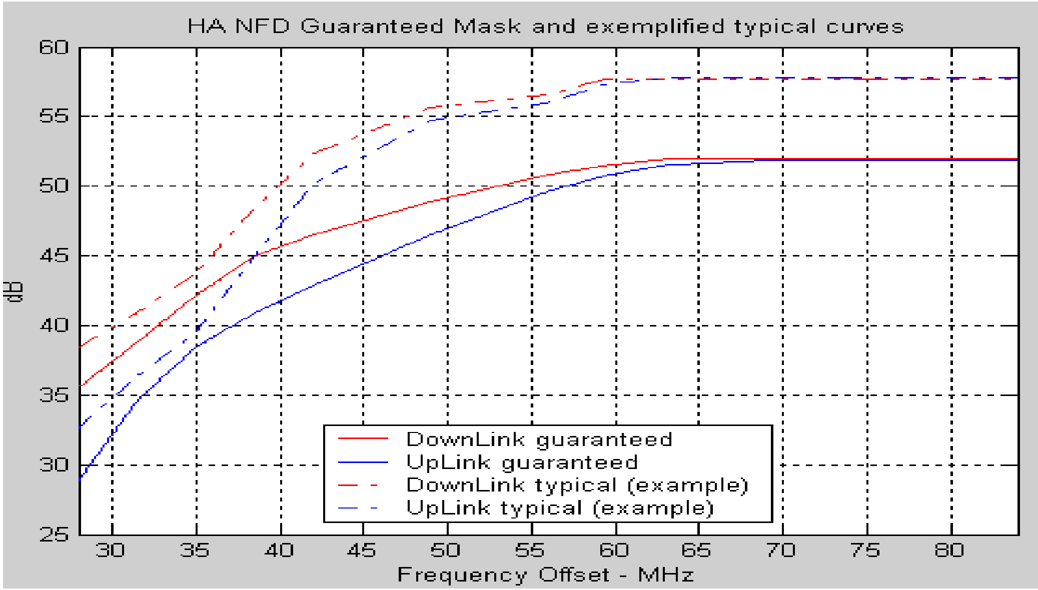



**Figure 41: HA NFD mask**

### 5.5.3.4 AT-transmit power time mask

The transmit power time mask parameters for each AT are derived under the condition that the number of active ATs per sector shall not exceed 256.

#### 5.5.3.4.1 H-FDD and TDD Tx/Rx switching time

Half-duplex ATs (both FDD and TDD) are not able to transmit and receive at the same time. Some minimum amount of time shall be specified for such ATs to pass from receive mode to transmit mode and vice-versa. Half-duplex ATs will typically power-up the Tx amplifier stages and (in case of H-FDD) change the frequency during this gap.

The switching time for H -FDD and TDD AT shall be 480 symbols (20 µs) and 48 symbols (2 µs), respectively (see figure 42).

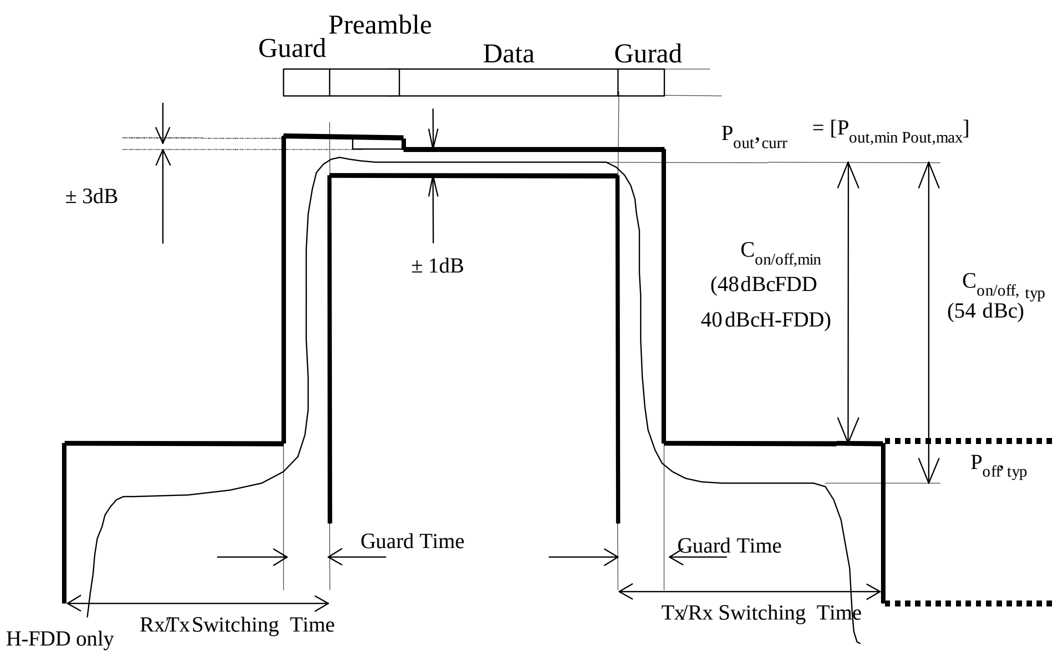



**Figure 42: AT power time mask**

**Table 28: Switching time for H FDD and TDD AT**

| | FDD | H-FDD | TDD |
|---|---|---|---|
| **Rx/Tx or Tx/Tx Switching time** | n.a. | 480 symbols<br>20 µs | 48 symbols<br>2 µs |

**Table 29: $C_{on/off}$ minimum requirements for UL TDMA transmission**

| Con/off vs. PHY mode | FDD (64 active ATs) | H-FDD (8 active ATs) | TDD (8 active ATs) |
|---|---|---|---|
| PHY 1 | 38 dB | 30 dB | 30 dB |
| PHY 2 | 42 dB | 34 dB | 34 dB |
| PHY 3 | 48 dB | 40 dB | 40 dB |

In figure 42 a typical burst of a half-duplex terminal is shown. Initially the terminal is in receive mode. The power amplifier is powered down and disconnected from the antenna with a switch and the emission level is basically at the noise floor. $t_{Rx/Tx}$ = 20 µs (Rx/Tx switching time) before the terminal is scheduled to transmit the Power On phase is started. $t_{Rx/Tx} - t_{rampup}$ (Ramp-up = 8 symbols = Guard Time) symbols later the ramp up phase is started. The power is raised from its current level to the actual transmit power. After the transmission of the preamble and the data symbols the ramp down phase $t_{rampdown}$ = 8 starts. Note that during the power up and power down phases other terminals are allowed to transmit.

#### 5.5.3.4.2 FDD

The same figures of $C_{on/off}$ as for Half-Duplex Terminals (both TDD and FDD) for the minimum requirement figures shall apply to Full-Duplex AT as well (see table 29), where the typical value for the noise floor, $P_{off}$ shall be 6 dB lower than the minimum requirement values, for PHY mode-3 resulting in $P_{off}$ = –54 dBc for 64 active FDD ATs. In case of higher number of FDD ATs, some further degradation on the receiver side shall be considered (e.g. max 0,5 dB for 256 ATs).

### 5.5.3.5 Transmit Power Control

#### 5.5.3.5.1 Dynamic downlink power control

In the downlink direction, different modulation schemes (PHY modes) shall be transmitted with equal rms power level.

Dynamic transmit power control can optionally be implemented in HA, in order to respect the regularity requirements.

In case dynamic DL power control being implemented, it shall comply with the following rules:

- DL power adjustments will be applied only after exploiting adaptive PHY mode procedure.
- The downlink power adjustment shall not exceed 1 dB every 50 ms, e.g. the slope cannot be sharper than 20 dB/s.
- The correction step shall not exceed ±1 dB.
- The transmit power shall respect the constant rms requirements within one frame.
- Power corrections shall be applied immediately before the frame preamble.
- The dynamic of power control will depend on the APT-classes. For APT-class-1 a dynamic of [0 - 4] dB, for ATP class-2 a dynamic of [0 - 7] dB and for ATP-class-3 a dynamic of [0 - 10] dB shall be considered.

#### 5.5.3.5.2 Static downlink power setting

Static transmit power setting can be optionally implemented in HA in order to offer a higher flexibility for the system deployment, e.g. different cell size.

In case of static DL power setting being implemented, it shall comply with the following rules:

- The power adjustment step shall have an accuracy of ±2 dB.
- The dynamic of power setting shall be [0 - 10] dB.

Note that the use of this option shall not jeopardize the coexistence issues.

#### 5.5.3.5.3 Uplink power control

The mandatory UL Power Control functionality in HA is under complete AP control.

Even if the specification of power control algorithm details is outside the scope of the present document, some basic aspects need to be addressed here, in order to guarantee minimum performances and interoperability for equipment coming from different vendors.

The Power Control function shall try to minimize interference. The algorithm (not standardized) shall be implemented in a way forcing each AT to never exceed the minimum Tx power level guaranteeing the achievement of the wanted link performances. The minimum Tx power level is intended, for each AT, whatever its distance from the APT and channel condition, the one guaranteeing not to exceed the maximum BER level (BER = $10^{-11}$) even in case of a maximum fade slope.

In order to achieve that, the APT shall manage to receive signals coming from every AT with an excess power (with respect to the nominal threshold for BER = $10^{-11}$); the gap in dB between actual Rx power and threshold Rx power is called *Rx Power Margin*.

The value of the *Rx Power Margin* shall belong to the range [4 - 8] (dB) from the nominal threshold for BER = $10^{-11}$. The actual value is left free to the implementation power control algorithm, provided that, in conjunction with the corresponding minimum repetition rate selected, minimum power control performances are fulfilled even considering maximum control loop lag.

For a given implementation, *Rx Power Margin* shall be the same for each PHY mode.

The following rules shall be followed in implementing Power Control algorithm.

- The power control level shall be adjusted in a relative manner (e.g. requests to increment the AT output power level will be given in relative steps with positive/negative increment indication).
- The absolute minimum time between ATPC control messages shall never be less than 50 ms, whatever the implementation of the power control algorithm. The actual minimum time can be implementation dependent, and shall belong to the range [50 – 200] ms.
- The size of all power control steps shall belong to the range [1 - 4] dB, with granularity of 0,5 dB, e.g. minimum nominal step shall be 0,5 dB and maximum nominal step shall be 4 dB.
- The relative transmitter accuracy shall be better than ±0,5 dB.
- The AT transmitter power control range shall be wider than 40 dB. Considering nominal AT output power at maximum setting, ($P_{max}$ = 14 dBm), the static power level at minimum setting ($P_{min}$) shall be not higher than –26 dBm.
- The On/Off power ratio ($C_{on/off}$) when transmitting the most efficient PHY mode shall be below the actual On level according to the reported figures given in table 29, whatever the carrier frequency in use and over the complete temperature range.

  At ambient temperature the typical $C_{on/off}$ ratio shall be at least 6 dBc higher than the minimum $C_{on/off}$.
- The C/N measurement accuracy at APT side shall be lower than ± 1 dB. The measured C/N shall have a resolution of 0,25 dB.

Note that the UL PHY mode change algorithm and UL power control are correlated. For the PHY mode change, the AT shall be able to communicate to the AP its *actual transmit power margin* as well.

### 5.5.4 Automatic Transmit Timing Control, ATTC

Some fine-tuning even after complete ranging process would be required to react on some changes. The exact algorithm will be out of the scope of the standardization process; where only the air-interface message format isspecified. The following rules shall be applied for the ranging and timing advance control:

- Dynamic at the first initialization: [0, 80] μs.
- Relative value control with step size: 1/4 symbol period.
- Correction accuracy at the AT: 1/2 symbol period.
- Dynamic range for fine tuning: [-2, 2] symbol period.
- Measurement accuracy at the AP: 1/4 symbol period.
- The periodicity of the initial ranging: Under the control of the AP (Manufacture design).
- The periodicity of the fine ranging: Under the control of the AP (Manufacture design).

### 5.5.5 Unwanted RF radiation

During the active transmit time, all emission shall fall within the spectral mask described in clause 5.5.3.3. During all the other modes, the emission shall be within the values given in clause 5.5.6. During each transition time gap, the radiated power shall follow the criteria described in clause 5.5.3.4. Outside the HIPERACCESS bands the emission shall be below the level described in clause 5.5.3.3, if regulatory requirements do not enforce more stringent limits.

### 5.5.6 Tx-spurious emissions

The equipment shall meet the requirements defined in:

- EN 301 997-1 [1].
- EN 301 213-1 [2].
- CEPT/ERC Recommendation 74-01 [5].
- EN 301 390 [4].

## 5.6 Receiver parameters

### 5.6.1 Rx spurious emissions (external)

The equipment shall meet the requirements defined in:

- EN 301 997-1 [1].
- EN 301 213-1 [2].
- CEPT/ERC Recommendation 74-01 [5].
- EN 301 390 [4].

### 5.6.2 Radio receiver performance

#### 5.6.2.1 Receiver sensitivity

The receiver sensitivity corresponding to a given C/N for an equivalent noise bandwidth $B_n$ and a noise figure NF is:

$$S_{th} = N_0 + NF + 10 \cdot \log_{10}(B_n) + \frac{C}{N} + \Delta loss + Rxloss$$

where:

- $\Delta$loss includes all implementation losses;
- Rxloss is the receiver branching filter loss.

Tables 30 and 31 show the required input level receiver thresholds for the AT and the AP in case of 4 X MAC PDUs per FEC block.

**Table 30: AT-Receiver sensitivity for different carrier frequencies**

| PHY mode, inner code rate | Outer code structure | C/N required, BER = $10^{-6}$ [dB] $C_0$ | $\Delta C_1/C_2$ | $P_{rx}$ @ 26 and 28 GHz ($C_0$) [dBm] | | $P_{rx}$ @ 32 GHz ($C_0$) [dBm] | | $P_{rx}$ @ 42 GHz ($C_0$) [dBm] | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | $10^{-6}$ | $10^{-11}$ | $10^{-6}$ | $10^{-11}$ | $10^{-6}$ | $10^{-11}$ |
| 4QAM,1/2 | RS(46,30) | 5 | +1 | -88 | -87 | -87 | -86 | -86 | -85 |
| 4QAM,2/3 | RS(232,216) | 8 | +1 | -85 | -84 | -84 | -83 | -83 | -82 |
| 4QAM,1 | RS(232,216) | 12 | +1 | -81 | -80 | -80 | -79 | -79 | -78 |
| 16QAM,7/8 | RS(232,216) | 18 | +1 | -75 | -74 | -74 | -73 | -73 | -72 |
| 64QAM,5/6 | RS(232,216) | 25 | +1 | -68 | -67 | -67 | -66 | -66 | -65 |
| 16QAM,1 | RS(232,216) | 20 | +1 | -73 | -72 | -72 | -71 | -71 | -70 |
| 64QAM,1 | RS(232,216) | 27 | +1 | -66 | -64 | -65 | -63 | -64 | -62 |

**Table 31: AP-Receiver sensitivity for different carrier frequencies**

| PHY mode, inner code rate | Outer code structure | C/N required, BER = $10^{-6}$ [dB] $C_0$ | $\Delta C_1/C_2$ | $P_{rx}$ @ 26 and 28 GHz ($C_0$) [dBm] | | $P_{rx}$ @ 32 GHz ($C_0$) [dBm] | | $P_{rx}$ @ 42 GHz ($C_0$) [dBm] | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | $10^{-6}$ | $10^{-11}$ | $10^{-6}$ | $10^{-11}$ | $10^{-6}$ | $10^{-11}$ |
| 4QAM,2/3 | RS(28,12) | 7 | +1 | -86 | -85 | -85 | -84 | -84 | -83 |
| 4QAM,2/3 | RS(236,220) | 8 | +1 | -85 | -84 | -84 | -83 | -83 | -82 |
| 4QAM,1 | RS(236,220) | 12 | +1 | -81 | -80 | -80 | -79 | -79 | -78 |
| 16QAM,7/8 | RS(236,220) | 18 | +1 | -75 | -74 | -74 | -73 | -73 | -72 |
| 16QAM,1 | RS(236,220) | 20 | +1 | -73 | -72 | -72 | -71 | -71 | -70 |

For detail about the derivation of this receiver sensitivity, please refer to annex C.

#### 5.6.2.2 Receiver dynamic

The receiver dynamic range is defined as the input power level dynamic range where receiver BER is never exceeding the threshold value of $10^{-6}$, whatever the RF carrier and equipment environmental temperature.

The BER performance is referred to all possible PHY modes specified for HIPERACCESS (in downlink or uplink) (Control zone PHY mode included).

Different requirements are foreseen for either the AP or the AT. This is because the ATPC functionality, which reduces receiver dynamic range, is mandatory only for the *uplink* direction. Based on that receiver dynamic range requirements will be more stringent in DL direction.

Receiver dynamic range requirements for HIPERACCESS are reported in table 32.

**Table 32: Receiver dynamic range requirements**

| | Minimum Rx Power level [dBm] | Maximum Rx Power Level [dBm] |
|---|---|---|
| **Access Point (AP)** | -86 | -56 |
| **Access Terminal (AT)** | -88 | -28 |

The lowest level of the dynamic range shall correspond to the lowest PHY mode sensitivity threshold and the highest level of the dynamic range shall correspond to the highest PHY mode sensitivity threshold.

For derivation details of these values, please refer to annex C.

## 5.7 Modulation accuracy

The accuracy of the waveform at the output of the transmitter is affected by many factors like transmit filter accuracy, D/A-converter, modulator imbalances, synthesizer phase noise and power amplifier nonlinearities.

The Error Vector Magnitude (EVM) for defining this accuracy is specified as follows:

$$EVM = \sqrt{\frac{\frac{1}{N}\sum_{1}^{N}(\Delta I^2 + \Delta Q^2)}{S_{\max}^2}} \times 100\,\%$$

Where $S_{max}$ is the outmost constellation point (see figure 43).

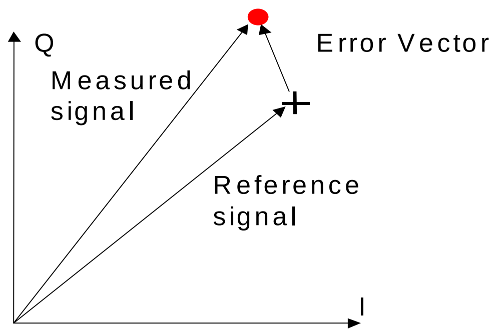



**Figure 43: Error Vector Magnitude measurement**

The required EVM can be estimated from the transmitter implementation margin if the error vector is considered noise which is added to the channel noise.

Where k = implementation margin, C/N = threshold signal to noise ratio, EV = noise from error vector, p is peak-to-average ratio for the constellation points.

The implementation margin means the excess power needed to keep the C/N constant when going from the ideal to the real transmitter. EVM cannot be measured at the antenna connector but should be measured by an "ideal" receiver with a certain carrier recovery loop bandwidth specified in % of the symbol rate. In table 33 the EVM-values for different modulation schemes are specified using parameters relevant to HA.

**Table 33: EVM values vs. modulation scheme**

| Modulation | Tx implementation margin | C/N (dB) | Peak-to-average | EVM (%) Without equalization | EVM (%) With equalization |
|---|---|---|---|---|---|
| 4QAM | 0,5 dB | 9 | 0 dB | 12 | 10 |
| 16QAM | 1,0 dB | 16 | 2,55 dB | 6 | 3 |
| 64QAM | 1,5 | 26 | 3,68 dB | n.a. | 1,5 |

Based on the values in table 33 the EVM values shall be the following:

- EVM 12 % and 6 % for 4QAM, 16QAM respectively when measured by an "ideal" receiver without an equalizer with a carrier recovery loop bandwidth of 1 % to 5 %; and
- EVM 10 %, 3 % and 1,5 % for 4QAM, 16QAM and 64QAM respectively when measured by an "ideal" receiver with an equalizer with a carrier recovery loop bandwidth of 1 % to 5 %.

The above EVM measured will include the transmit filter accuracy, D/A-converter, modulator imbalances, untracked phase noise and PA non-linearity.

# 5.8 Switching and load levelling times

## 5.8.1 Transmitter ramping time

The ramp up and ramp down time for each UL burst shall be both 8 symbols.

Regarding the contents of these 8 symbols different possibilities may exist, where each of them shall not have an impact on the interoperability and the coexistence issue. Therefore, by respecting the time-mask the contents of the guard-time is not specified and it is up to the manufacture how to fill it.

## 5.8.2 TDD switching time

The TDD AT and AP shall have a PHY Tx/Rx or Rx/Tx switching time of 48 symbols (corresponding to about 2 us). This time corresponds to the PHY layer to switch from the transmission mode to the reception mode, or vice versa.

## 5.8.3 Load levelling and carrier recovery time

From the PHY perspective, the time required for either changing from one frequency to another or recovering the same frequency (e.g. after short interruption, where the first initialization is already done), shall be lower than 100 ms. In other words, all PHY synchronization i.e. frame/carrier/clock recovery and Control zone in DL shall be locked in less than 100 ms.

# 5.9 Network management issues

For the network management purposes, the PHY layer should provide means for performance monitoring and change of PHY parameters.

For performance monitoring purposes two standards will be applied:

- Radio link quality monitoring: ITU-T Recommendations G.826 [12], G.821 [11], G.827 [15] and M.2100 Series [26].
- Logical link quality monitoring: In case of ATM: ITU-T Recommendation I.356 (see bibliography).

# 5.10 Antennas and EIRP classes

## 5.10.1 APT

In case of the APT, different classes are foreseen depending on the type of antenna in use, as reported in table 34. Each APT class corresponds to a given EIRP value.

The APT classes are frequency band and sector angle–independent.

The accuracy of antenna gain shall be better than ±1 dB over temperature.

The overall EIRP accuracy will be the sum of antenna gain and Tx output power accuracy.

The EIRP is reported using nominal output power levels at maximum settings.

APT class 1 is the default class, corresponding to minimum system gain.

**Table 34: APT classes, antenna gains and EIRP**

| APT class | Nominal antenna gain | Tx maximum output power | Nominal EIRP | Maximum EIRP | Azimuth radiation pattern |
|---|---|---|---|---|---|
| 1 | 18 dBi | +15 dBm | +33 dBmi | +36 dBmi | CS3; EN 301 215-2 [28], EN 301 215-3 [29], EN 301 215-4 (see note) |
| 2 | 21 dBi | +15 dBm | +36 dBmi | +39 dBmi | CS3; EN 301 215-2 [28], EN 301 215-3 [29], EN 301 215-4 (see note) |
| 3 | 24 dBi | +15 dBm | +39 dBmi | +42 dBmi | CS3; EN 301 215-2 [28], EN 301 215-3 [29], EN 301 215-4 (see note) |
| NOTE: Currently still in Draft state (see bibliography). | | | | | |

## 5.10.2 AT

In case of the AT, different antenna gains are foreseen depending on the frequency band in use, as reported in table 35. Different nominal (and maximum) EIRP values will be available each frequency band.

The accuracy of antenna gain shall be better than ±1 dB over temperature.

The overall EIRP accuracy will be the sum of antenna gain and Tx output power accuracy.

The EIRP is reported using nominal output power levels at maximum settings.

**Table 35: AT antenna gains and EIRP**

| Frequency band | Nominal antenna gain | Tx maximum output power | Nominal EIRP | Maximum EIRP | Radiation pattern |
|---|---|---|---|---|---|
| 42 GHz | 37 dBi | +14 dBm | 51,0 dBmi | 54,0 dBmi | TS3; EN 301 215-3 [29] |
| 32 GHz | 35,5 dBi | +14 dBm | 49,5 dBmi | 52,5 dBmi | TS3; EN 301 215-4 (see note) |
| 28 GHz | 34,5 dBi | +14 dBm | 48,5 dBmi | 51,5 dBmi | TS3; EN 301 215-2 [28] |
| 26 GHz | 33,5 dBi | +14 dBm | 47,5 dBmi | 50,5 dBmi | TS3; EN 301 215-2 [28] |
| NOTE: Currently still in Draft state (see bibliography). | | | | | |

General aspects relevant to antenna specifications are reported in ETSI EN 301 215-1 [27].

Reference documents for each specific band are reported in the following clauses, for both APT and AT.

## 5.10.3 Antenna for 42 GHz Band (40,5 GHz to 43,5 GHz)

Refer to EN 301 215-3 [29].

## 5.10.4 Antenna for 31 GHz and 32 GHz Bands (31,0 GHz to 31,8 GHz; 31,8 GHz to 33,4 GHz)

Refer to EN 301 215-4 (see bibliography).

## 5.10.5 Antenna for 26 GHz and 28 GHz Bands (24,25 GHz to 26,5 GHz; 27,5 GHz to 29,5 GHz)

Refer to EN 301 215-2 [28].

# 5.11 Polarization

Both vertical and horizontal polarization can be used. The use of a given polarization is deployment specific. The use of the same polarization for the same channel for the UL as well for the DL is recommended.

# 5.12 Summary of PHY layer parameters

## 5.12.1 Negotiated/broadcast PHY layer parameters

The summary of the essential PHY layer parameters that shall be communicated to the PHY layer from the higher layer are given in table 36.

**Table 36: List of PHY parameters negotiated/Broadcast (e.g. during first initialization)**

| Parameters | APT side | AT side | Description |
|---|---|---|---|
| UL Preamble length | Dictates (see note) | | 16 or 32 symbols |
| Frame Offset | Dictates | | From 0,25 ms up to 1 ms |
| DL TDMA capability | Implied by the DL Map | Reports capability | Optionally supported by the APT |
| Burst concatenation | Implied by the DL Map | | Optionally supported by the APT |
| Modulation capability | | Reports capability | 16QAM for the UL (optional for AT) and 64QAM for the DL (optional for APT) |
| Turbo code capability | | Reports capability | Encoder in AT and decoder in AP (optional for both APT and AT) |
| AT-max transmit power for 16QAM | | Reports capability | From 11 dBm to 14 dBm |
| H-FDD capability | Implied by the DL Map | Reports capability | |
| Number of PDU per FEC block in the UL | Implied by the DL Map | | Single PDU per FEC block option |
| NOTE: Message broadcast. | | | |

## 5.12.2 Physical layer measurement parameters

### 5.12.2.1 Rx measurement parameters

The summary of the PHY layer parameters that are measured in the Rx receiver side (both APT and AT) are given in table 37. These parameters are also needed for the higher layers (DLC and NMS).

**Table 37: List of PHY Parameters measured in Rx**

| Parameters | Description |
|---|---|
| PER /BER | Packet/Bit Error Rate |
| RS-Error-Flag | Error detection flag by Reed-Solomon decoder, might be used for ARQ and PER estimation purposes |
| CNR | Carrier to noise Ratio |
| Rx Power Level | Received power level |
| Performance monitoring data as ITU-T Recommendations G.826 [12] and G.821 [11] | See performance monitoring |

### 5.12.2.2 Tx Measurement Parameters

The summary of PHY layer parameters that are measured in the transmitter side Tx are given below:

- Transmitter *power margin reserve.*
- Transmitter power level.

These parameters are also needed to the higher layers (DLC and NMS).

# Annex A (informative): Analysis of the HIPERACCESS radio coexistence

Scope of this annex is to analyse the radio co-existence of HIPERACCESS systems operating in the same geographical area, with adjacent frequency blocks, and estimate, in accordance with the relevant EEC Reports and Recommendations ([16], [14], [17] and [18]) the guard band required in order to guarantee reasonable interference free deployments. Three main scenarios will be analysed:

- Radio co-existence among the HIPERACCESS APTs deployed in same or different sectors and in same or different cells by an operator in his own assigned frequency block (Intra-operator/Intra-system co-existence).
- Radio co-existence between an operator operating an HIPERACCESS system and an operator operating any other system (Inter-operator/Inter-system co-existence).
- Radio co-existence between operators both operating HIPERACCESS systems (Inter-operator/Intra-system co-existence).

Note that the HIPERACCESS parameters of main relevance for this radio co-existence analysis, specified in the physical layer technical specification main body, are summarized in annex E.

# A.1 Intra-operator/Intra-system co-existence

The radio co-existence among the APTs deployed in same or different sectors and in same or different cells by an operator operating HIPERACCESS system is guaranteed by means of the conformance to the HIPERACCESS parameters defined in the main core of this physical layer technical specification, such as NFD mask, Tx masks, Tx powers and allowed tolerances, antenna gain and allowed tolerances, C/N and Rx thresholds. Operators can freely deploy adjacent carriers in same or adjacent sectors and co-channel carriers at a pre-determined distance with no particular constraints on the cell planning strategy.

Note that the operators shall carefully deploy HIPERACCESS systems, in the same continuous coverage area, by means of APTs belonging to the same class for avoiding increase of self-interference.

# A.2 Inter-operator/Inter-system co-existence

This part deals with the radio co-existence between an operator operating an HIPERACCESS system and an operator operating any other system, in the same area with adjacent frequency blocks.

## A.2.1 Coexistence in the 42 GHz band

Emissions from one operator's frequency block into a neighbouring block are regulated, in the recommendation CEPT/ECC Recommendation 01-04 [14], by means of a frequency block edge EIRP density emission mask. This block edge mask enables the operators to place the outermost radio channels with suitable guard-bands, inside their assigned block, in order to avoid co-ordination with the neighbouring blocks.

In figures 44, 45 and 46, the 42 GHz block edge masks stated by CEPT/ECC Recommendation 01-04 [14] are depicted together with the HIPERACCESS downlink (DL) and uplink (UL) absolute EIRP density spectrum masks, computed from the HIPERACCESS relative spectrum mask (see clause 5.5.3.3 of the present document) and from the maximum EIRP value, related to the HIPERACCESS APT classes (see table E.2, annex E).

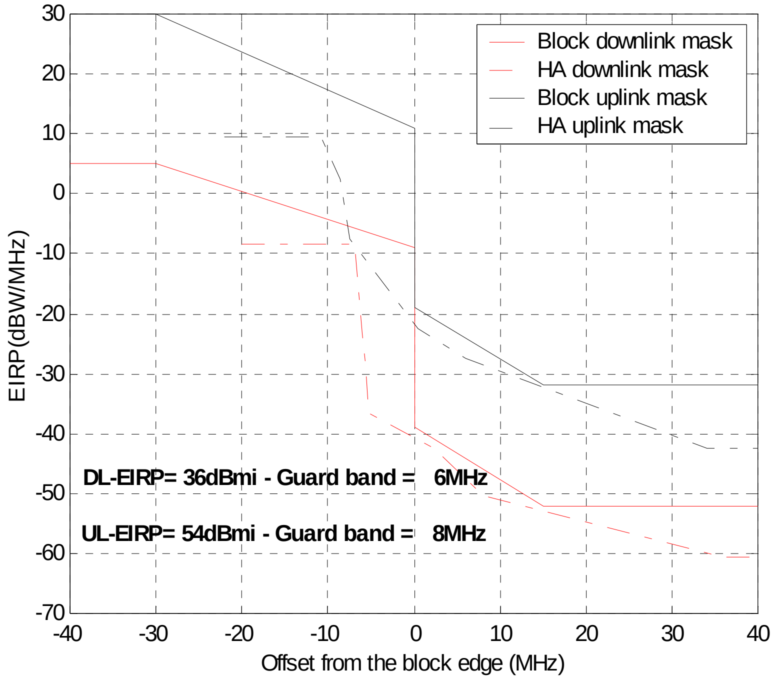



**Figure A.1: UL and DL block edge masks and HA EIRP density spectrum with guard bands (APT class 1, 42 GHz, no power control)**

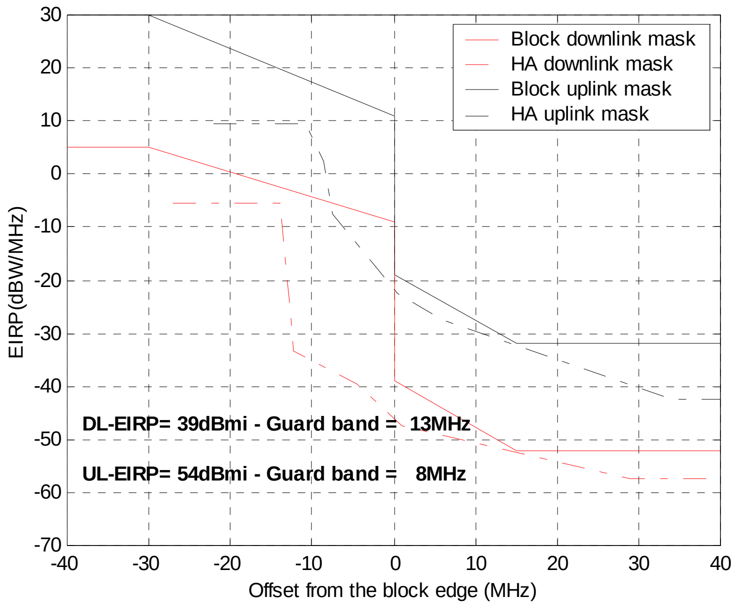



**Figure A.2: UL and DL block edge masks and HA EIRP density spectrum with guard bands (APT class 2, 42 GHz, no power control)**

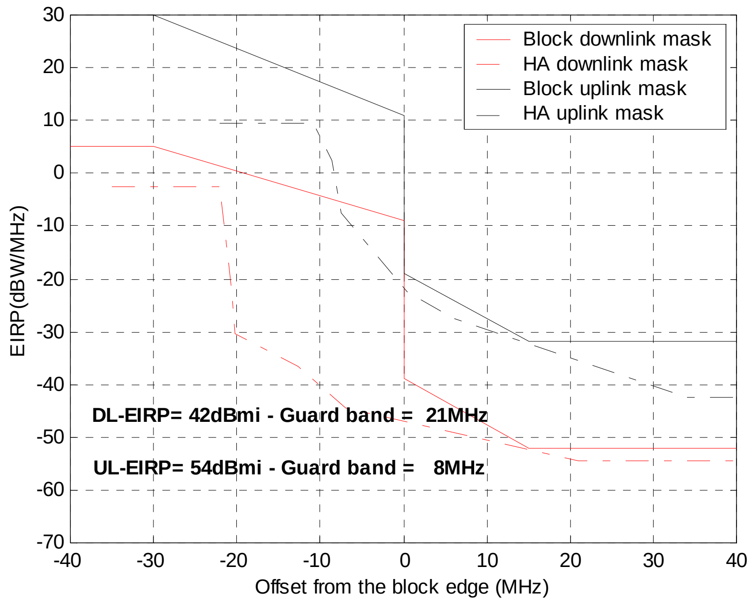



**Figure A.3: UL and DL block edge masks and HA EIRP density spectrum with guard bands (APT class 3, 42 GHz, no power control)**

In figure A.4, the 42 GHz block edge masks are instead depicted together with the HIPERACCESS downlink (DL) and uplink (UL) absolute EIRP density spectrum masks, when the ATPC factor is included. The APTC factor takes into account that, in clear sky condition, the transmitted power is relevantly lower than the maximum allowed. This factor is assumed to be 10 dB for uplink and respectively 4 dB (APT class 1), 7 dB (APT class 2) and 10 dB (APT class 3) for the downlink. Note that in the HIPERACCESS system, the ATPC functionality is mandatory for the ATs but optional for the APTs.

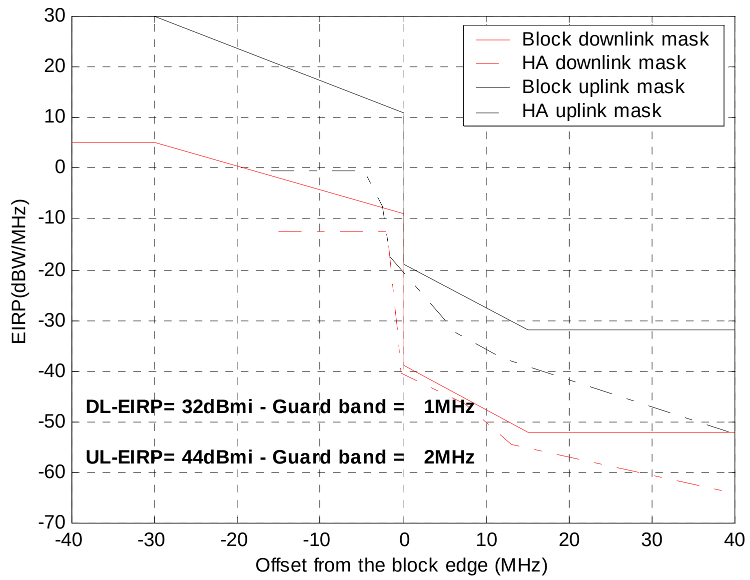



**Figure A.4: UL and DL block edge masks and HA EIRP density spectrum with guard bands (all APT classes, 42 GHz, with power control)**

The impact of the different APT classes on guard bands, driven by the need of respecting the block edge mask imposed by CEPT/ECC Recommendation 01-04 [14] is summarized in table A.1.

**Table A.1: Maximum guard band size requirements per block**

| APT class | Maximum guard band (MHz) | Guard band, examples when including the ATPC factor (MHz) |
|---|---|---|
| 1 (Default) | 8 | 2 |
| 2 | 13 | 2 |
| 3 | 21 | 2 |

Note that the guard bands are symmetric (i.e. same for both DL and UL) and driven by UL for the class 1 and by DL for the classes 2 and 3. As the frequency block assigned to operators is usually per region, the APT classes would allow operators to deploy HA systems, which in high-density areas can be optimized for traffic (e.g. using class 1 and saving band), while in low-density areas can be optimized for coverage (e.g. using class 2 or 3 and sacrificing unused band).

Note that the CEPT/ECC Recommendation 01-04 [14] states that the block edge mask limits are absolute maximum and intended to include tolerances and any ATPC range, therefore the guard band figures shown in the right column of the table A.1 are just for exemplification.

### A.2.1.1 Interference rejection of the HIPERACCESS receiver

The 42 GHz block edge masks, stated by CEPT/ECC Recommendation 01-04 [14], can also be used in order to estimate the maximum interference level to be expected at the HIPERACCESS receiver side, when the interfering transmitter is assumed to be at a certain assumed distances between interfer and victim (see annex D).

#### A.2.1.1.1 Receiver interference rejection for the DL and UL interference scenarios

This interference scenario is verified in case of both FDD and TDD or mixed TDD/FDD system deployments, when an "other system" APT- interferes the HA AT or an "other system" AT- interferes the HA APT.

As shown in annex D, a guard band of 2 MHz is typically able of protecting the HA receiver from the block edge mask out-of-band emission, whatever is the APT class in use. The guard band requirements are therefore confirmed to be driven by the transmission side (see clause A.2.1).

#### A.2.1.1.2 Receiver interference rejection for the APT to APT interference scenarios

This interference scenario is only verified in case of TDD or mixed TDD/FDD system deployments, when an "other system" APT interferes the HIPERACCESS APT.

Table A.2 summarizes the guard band requirements for the various APT classes, as evaluated in the annex D.

**Table A.2: Maximum guard band size required by the receiver side**

| APT class | Maximum guard band per block (MHz) |
|---|---|
| 1 (Default) | 2 |
| 2 | 9 |
| 3 | ~28 |

Therefore, for the APT class 1, the guard band requirements are likely to be fully driven by the transmission side (see table A.1).

For the APT class 2, the guard band requirements are likely to be driven by the transmission side (see table A.1). Note that the possible improvement due to the ATPC factor cannot be anymore considered as the APTc2 receiver side is likely to require a guard band larger than the Tx side (9 MHz against 2 MHz).

For the APT class 3, the guard band requirements, for the APT class 3, are likely to be fully driven by the receiver side. Note that with the strict application of the block edge mask, the APT class 3 cannot specify the real guard band requirement: the 28 MHz guard band, estimated in table A.2, is either based on the assumption that manufacturers are likely to improve the typical Tx out-of-band emission by a few dBs or on the relaxation of the threshold degradation requirement.

### A.2.2 Coexistence in the 26/28 GHz bands

Emissions from one operator's frequency block into a neighbouring block are regulated, in the recommendation CEPT/ERC Recommendation 01-03 [17], CEPT/ERC Recommendation 00-05 [18] and ERC Report 99 [16], by means of imposing fixed guard bands between the assignments. This enables the operators to avoid co-ordination with the neighbour blocks.

Please note that the ERC/Report 99 document [16] is currently under revision and its results shall be used for later deployment.

### A.2.3 Coexistence in the 32 GHz bands

Guidelines from EEC are not currently available. The studies that are on going refer to the strategies and methodologies already used for the 42 GHz and/or 26 GHz/28 GHz bands.

### A.2.4 Co-operative deployment

Notwithstanding that the block edge mask or the fixed guard band requirements are, for the uncoordinated deployment cases, stated by CEPT/EEC Recommendation 01-04 [14], CEPT/ERC Recommendation 01-03 [17] and CEPT/ERC Recommendation 00-05 [18], all these recommendations foresee and encourage the co-operative deployment in order further enhancing the spectrum efficiency.

When the neighbouring operators agree a mutual co-operation, the administrations are expected to allow repealing the requirement imposed in terms of block edge mask or fixed guard bands.

The ERC Report 99 [16] characterizes two ways of co-operative deployments:

- By means of co-ordinated cell planning; e.g. avoiding that the adjacent channels are used in the same sector area with same polarization; or

- By means of site sharing; it provides that useful and interfering signals have similar paths (avoiding the possibility that interference path is much smaller than the victim one and avoiding un-correlated rain propagation). Note that the site sharing solution is only applicable for HIPERACCESS FDD systems while HIPERACCESS TDD systems shall require a very careful site engineering (e.g. specific vertical and horizontal antenna separations) and good knowledge of the behaviour of the other co-sited system.

## A.3 Inter-operator/Intra-system co-existence

The Intra-operator/Intra-system co-existence is the coexistence among neighbour operators operating HIPERACCESS systems, in the same area with adjacent frequency blocks.

It can be considered as a particular case of the co-operative deployment scenario but the operators are not constrained to co-ordinate, with the competitors, cell planning or site acquisition as in the previous case, described in clause A.2.4.

In practice the HIPERACCESS operators can increase the spectrum efficiency, by decreasing the need for guard bands, just thank to the simple knowledge that the neighbouring operator also operates an HIPERACCESS system, which is very likely to be a public information. In practice these operators would be able to still operate uncoordinated deployment, i.e. independent choice of the AP locations and of the more suitable cell planning strategy with no need of compromises or of sharing of strategic information.

### A.3.1 The ERC report 99 "ISOP" methodology based on ERC/Report 99

The methodology used for the estimation of the guard bands, in the APT to AT (AP to AT and AT to AP) interference scenarios, is the one proposed by the ERC report 99 (shortly described in annex B) [16], adapted to the specific HIPERACCESS system parameter and deployment in the various frequency bands.

The ERC Report 99 [16] estimates, for the AP-AT and AT-AP cases, the Interference Scenario Occurrence Probability (ISOP), which is defined as the probability that an operator places at least one terminal in the interference area, and consequentially calculates the minimum distance "dmin" above which the probability of suffering interference is lower than the target value, defined as ISOP = 1 %.

Using the HA system parameters described in annex E, we evaluate, in the next clauses, the actual interference level, at the AT or APT antenna connectors.

## A.3.1.1 Estimation of the "minimum distances"

In annex B and the HA system parameters shown in annex E, table A.3 shows respectively the HIPERACCESS coverage range (sector diagonal) in the various frequency bands, for the rain zones E and K, and the minimum distances, for the 1 % ISOP target. The APT class 1 is used for computations. The last column of the table also shows the typical rain cell diameter, in accordance with: "The Spatial Structure of Rain and its Impact on the Design of Advanced TLC Systems"; "A Comprehensive Meteorologically Oriented Methodology for the Prediction of Wave Propagation Parameters in Telecommunication Applications Beyond 10 GHz"; "Data and Theory for a New Model of the Horizontal Structure of Rain Cells for Propagation Applications"; "The effect of precipitation on Microwave LMDS Networks - Performance Analysis Using a Physical Rain Cell Model" (see bibliography).

**Table A.3: Estimation of the "minimum distances" vs. frequency bands and rain zones for APT class 1**

| | 42 GHz (99,985 %) | 32 GHz (99,99 %) | 28 GHz (99,99 %) | 26 GHz (99,99 %) | Rain cell diameter (km) |
|---|---|---|---|---|---|
| **K zone –HA coverage range (km)** | 2,2 | 2,6 | 3,2 | 3,5 | 2,45 |
| **E zone –HA coverage range (km)** | 3,3 | 4,1 | 5,1 | 5,5 | 2,58 |
| **"1 % ISOP" minimum distance (km)** | 1,4 | 0,8 | 0,7 | 0,7 | - |

Note that the rain zone, which provides the worst case "minimum distance", is the one with the smallest (and positive) sector size and rain cell size ratio. Therefore the "minimum distances", considered for interference level estimations, will be the one resulting from the rain zone E, for the 42 GHz and 32 GHz bands, and from rain zone K, for the 28 GHz and 26 GHz bands.

### A.3.1.1.1 Minimum distance vs. APT classes

Table A.4 exemplifies the relation between the minimum distance in the 26 GHz band and the APT classes under the assumption that the related sector angles are the one described in annex E, table E.2.

**Table A.4: Minimum distance vs. APT classes, 26 GHz band**

| | APT c1 | APT c2 | APT c3 |
|---|---|---|---|
| **K zone –HA coverage range at 99,99 %, 26 GHz (km)** | 3,5 | 3,8 | 4,3 |
| **"1 % ISOP" minimum distance (km)** | 0,7 | 1 | 1,6 |
| **Interference link budget decrease in respect to ATPc1 (dB)** | - | -0,1 | -1,2 |

The interference link budget indicates that the APT class 1 provides the worst-case scenario (e.g. APT class 2 has 3 dB more EIRP in respect to APT class 1 but the increased minimum distance provides an increased free space loss attenuation [20 X  log (1/0,7) = 3,1 dB], which exceeds the EIRP impairment).

Therefore the "minimum distances", considered for interference level estimations, will be the one resulting from the APT class 1.

## A.3.2 Downlink (AP-AT) co-existence scenario

The APT to AT interference scenario is verified in case of both FDD and TDD or mixed TDD/FDD HIPERACCESS system deployments.

### A.3.2.1 Estimation of the interference level and guard band requirements

The value of the interference is evaluated according to the free space loss criterion as expressed in the following:

$$I = Pout + Gt + Gn - 92{,}4\ dB - 20 \times \log(F) - 20 \times \log(dmin) - Atm - Kc \qquad (A.1)$$

where F is the frequency of operation;

Pout is 15 dBm;

Gn (APT antenna) is 18 dB;

Gt (AT antenna) is as for table E.1, annex E;

Kc is the rain correlation factor, here assumed to be 3 dB for the 32/42 GHz and 2 dB for the 26/28 GHz bands (see annex E);

dmin is as for table A.3; and

Atm is the atmospheric absorption according to the ITU-R Recommendation P.676-5, annex 2 [30] and according to the following data:

- Pressure: 1 013 hPa, Temperature: 15° C, Water vapour: According to ITU-R Recommendation P.835-3, clause 3.1 (summer profile) [31];
- Water vapour density: related to the 0 m to 400 m antenna altitude and to the middle latitude (45°).

Considering that C/I_adj is the carrier to interference ratio resulting when the interference is not co-channel and that C/I_th = C/I_adj + NFD and C/I_adj = C_th – I, then the NFD level needed in order to meet the required C/I threshold, is:

$$NFD = C/I\_th - C\_th + I \qquad (A.2)$$

Using the system parameters, summarized in annex E, and from equation A.2, the NFD requirements are derived (without ATPC). The resulting figures are shown in table A.5.

**Table A.5: DL NFD requirements vs. APT classes and frequency bands**

| | NFD requirement (dB) | | |
|---|---|---|---|
| **Bands** | **APTc1** | **APTc2** | **APTc3** |
| **42 GHz** | 36,0 | 39,0 | 42,0 |
| **32 GHz** | 42,7 | 45,7 | 48,7 |
| **28 GHz** | 46,0 | 49,0 | 52,0 |
| **26 GHz** | 46,0 | 49,0 | 52,0 |

Note that the evaluation of the NFD requirement does not depend on the considered PHY mode as the increased C/I_th value is perfectly compensated by the decrease of the C_th figures.

In accordance to the NFD masks in figure E.1, annex E, and from the NFD requirement in table A.5, the maximum and typical guard band requirement can be derived. Table A.6 shows the resulting figures.

**Table A.6: Maximum and typical expected guard band per block (MHz) – DL interference scenario**

| | Interfering | | | | | |
|---|---|---|---|---|---|---|
| | APTc1 | | APTc2 | | APTc3 | |
| **Bands** | **Max.** | **Typ.** | **Max.** | **Typ.** | **Max.** | **Typ.** |
| **42 GHz** | 0,0 | **0,0** | 2,0 | **1,0** | 3,5 | **2,5** |
| **32 GHz** | 4,0 | **3,0** | 6,0 | **4,0** | 10,0 | **5,0** |
| **26/28 GHz** | 6,5 | **4,0** | 11,5 | **5,5** | 16,5 | **7,0** |

# A.3.3 Uplink (AT to AP) co-existence scenario

The APT to AT interference scenario is verified in case of both FDD and TDD or mixed TDD/FDD HIPERACCESS system deployments.

## A.3.3.1 Estimation of the interference level and guard band requirements

The value of the interference is evaluated according to the free space loss criterion as expressed in the following:

$$I = Pout + Gt + Gn - 92{,}4\ dB - 20\ X\ \log(F) - 20\ X\ \log(dmin) - Atm - Af - Kc \quad (A.3)$$

where F is the frequency of operation;

Pout is 14 dBm;

Gn, Gt, Kc, dmin, Atm are as defined for (A.1);

Af is the ATPC factor, here assumed to be 10 dB.

Considering that C/I_adj is the carrier to interference ratio resulting when the interference is not co-channel and that C/I_th = C/I_adj + NFD and C/I_adj = C_th – I, then the NFD level needed in order to meet the required C/I threshold, is:

$$NFD = C/I\_th - C\_th + I \quad (A.4)$$

Using the system parameters, summarized in annex E, and from equation A.4, the NFD requirements are derived (without ATPC). The resulting figures are shown in table A.7.

**Table A.7: UL NFD requirements vs. APT classes and frequency bands**

| | NFD requirement (dB) | | |
|---|---|---|---|
| **Bands** | **APTc1** | **APTc2** | **APTc3** |
| **42 GHz** | 25,0 | 28,0 | 31,0 |
| **32 GHz** | 31,7 | 34,7 | 37,7 |
| **28 GHz** | 32,8 | 35,8 | 38,8 |
| **26 GHz** | 34,0 | 37,0 | 40,0 |

Note that the evaluation of the NFD requirement does not depend on the considered PHY mode as the increased C/I_th value is perfectly compensated by the decrease of the C_th figures.

In accordance to the NFD masks in figure E.1, annex E, and from the NFD requirement in table A.7, the maximum and typical guard band requirement can be derived. Table A.8 shows the resulting figures.

**Table A.8: Maximum and typical expected guard band per block (MHz) – UL interference scenario**

| | Victim | | | | | |
|---|---|---|---|---|---|---|
| | APTc1 | | APTc2 | | APTc3 | |
| **Bands** | **Max** | **Typ.** | **Max.** | **Typ.** | **Max.** | **Typ.** |
| **42 GHz** | 0,0 | **0,0** | 0,0 | **0,0** | 0,5 | **0,0** |
| **32 GHz** | 1,0 | **0,0** | 2,0 | **1,0** | 3,5 | **2,5** |
| **26/28 GHz** | 2,0 | **1,0** | 3,5 | **2,5** | 5,0 | **4,0** |

Note that the guard bands in table A.8 are always better than the ones in table A.6. The guard bands shall be symmetric (i.e. same for both DL and UL), therefore the APT to AT interference scenario is driven by the DL.

# A.3.4 AP to AP co-existence scenario

The APT to AT interference scenario is verified in case of both FDD and TDD or mixed TDD/FDD HIPERACCESS system deployments.

The FDD HIPERACCESS systems deployments can experience AP to AP co-existence problems only for the cases relevant to the 42 GHz band (where no default centre gap is defined) and limited to the "last frequency block" of the lower band and the "first frequency block" of the upper band.

## A.3.4.1 The ERC report 99 "worst case" methodology based on ERC/Report-99

The methodology used for the estimation of the guard bands, in the AP to AP interference scenarios, is the one proposed by the ERC Report 99 [16].

In the ERC Report 99 [16], the probabilistic ISOP approach, used for the APT to AT case, is not considered as safe for the AP to AP case. The worst-case method derives system deployment parameters to ensure that interference is always below a set threshold for all cases. Clause A.3.1.3.1 estimates the interference level and guard band requirement for a minimum AP-to-AP distance that is assumed to be 200 m.

### A.3.4.1.1 Estimation of the interference level and guard band requirements

The value of the interference is evaluated according to the free space loss criterion as expressed in the following:

$$I = Pout + Gn + Gn - 92{,}4\ dB - 20\ X\ \log(F) - 20\ X\ \log(dmin) - Atm - Kc \qquad (A.5)$$

where F is the frequency of operation;

Pout is 15 dBm;

Gn (APT antenna) is as for table E.1, annex E;

Kc is the rain correlation factor, here assumed to be 0 dB;

dmin can be considered in the range of 0,2 km; and

Atm is the atmospheric absorption.

Considering that C/I_adj is the carrier to interference ratio resulting when the interference is not co-channel and that C/I_th = C/I_adj + NFD and C/I_adj = C_th – I, then the NFD level needed in order to meet the required C/I threshold, is:

$$NFD = C/I\_th - C\_th + I \qquad (A.6)$$

Using the system parameters, summarized in annex E, and from equation A.6, the NFD requirements are derived. For different carrier frequencies: from 42 GHz to 26 GHz. The resulting figures are shown in tables A.9, A.10, A.11 and A.12.

**Table A.9: NFD requirements vs. APT classes in the 42 GHz bands**

| | | Victim | |
|---|---|---|---|
| **Interfering** | **APTc1** | **APTc2** | **APTc3** |
| **APTc1** | 37,1 | 40,1 | 43,1 |
| **APTc2** | 40,1 | 43,1 | 46,1 |
| **APTc3** | 43,1 | 46,1 | 49,1 |

**Table A.10: NFD requirements vs. APT classes in the 32 GHz bands**

| | Victim | | |
|---|---|---|---|
| **Interfering** | **APTc1** | **APTc2** | **APTc3** |
| **APTc1** | 40,3 | 43,3 | 46,3 |
| **APTc2** | 43,3 | 46,3 | 49,3 |
| **APTc3** | 46,3 | 49,3 | 52,3 |

**Table A.11: NFD requirements vs. APT classes in the 28 GHz bands**

| | Victim | | |
|---|---|---|---|
| **Interfering** | **APTc1** | **APTc2** | **APTc3** |
| **APTc1** | 42,5 | 45,5 | 48,5 |
| **APTc2** | 45,5 | 48,5 | 51,5 |
| **APTc3** | 48,5 | 51,5 | 54,5 |

**Table A.12: NFD requirements vs. APT classes in the 26 GHz bands**

| | Victim | | |
|---|---|---|---|
| **Interfering** | **APTc1** | **APTc2** | **APTc3** |
| **APTc1** | 43,4 | 46,4 | 49,4 |
| **APTc2** | 46,4 | 49,4 | 52,4 |
| **APTc3** | 49,4 | 52,4 | 55,4 |

Note that the evaluation of the NFD requirement does not depend on the considered PHY mode as the increased C/I_th value is perfectly compensated by the decrease of the C_th figures.

In accordance to the NFD masks in figure E.1, annex E, and from the NFD requirement tables A.9, A.10, A.11 and A.12, the maximum and typical guard band requirement can be derived for different carrier frequency as well. Tables A.13, A.14, A.15 and A.16 show the resulting figures.

**Table A.13: Maximum and typical expected guard band per block (MHz) - 42 GHz**

| **Interfering** | Victim | | | | | |
|---|---|---|---|---|---|---|
| | **APTc1** | | **APTc2** | | **APTc3** | |
| | **Max.** | **Typ.** | **Max** | **Typ.** | **Max** | **Typ.** |
| **APTc1** | 1,0 | **0,0** | 2,0 | **1,0** | 4,5 | **3,5** |
| **APTc2** | 2,0 | **1,0** | 4,5 | **3,5** | 6,5 | **3,5** |
| **APTc3** | 4,5 | **3,5** | 6,5 | **3,5** | 11,0 | **7,5** |

**Table A.14: Maximum and typical expected guard band per block (MHz) - 32 GHz**

| | Victim | | | | | |
|---|---|---|---|---|---|---|
| | **APTc1** | | **APTc2** | | **APTc3** | |
| **Interfering** | **Guar.** | **Typ.** | **Guar.** | **Typ.** | **Guar.** | **Typ.** |
| **APTc1** | 2,5 | **1,0** | 4,5 | **3,5** | 6,5 | **3,5** |
| **APTc2** | 4,5 | **3,5** | 6,5 | **3,5** | 11,0 | **7,5** |
| **APTc3** | 6,5 | **3,5** | 11,0 | **7,5** | 17,0 | **7,0** |

**Table A.15: Maximum and typical expected guard band per block (MHz) - 28 GHz**

| | Victim | | | | | |
|---|---|---|---|---|---|---|
| | APTc1 | | APTc2 | | APTc3 | |
| **Interfering** | **Guar.** | **Typ.** | **Guar.** | **Typ.** | **Guar.** | **Typ.** |
| **APTc1** | 4,0 | **2,5** | 5,0 | **4,0** | 10,0 | **5,0** |
| **APTc2** | 5,0 | **4,0** | 10,0 | **5,0** | 14,0 | **6,5** |
| **APTc3** | 10,0 | **5,0** | 14,0 | **6,5** | n.a. | **9,0** |

**Table A.16: Maximum and typical expected guard band per block (MHz) - 26 GHz**

| | Victim | | | | | |
|---|---|---|---|---|---|---|
| | APTc1 | | APTc2 | | APTc3 | |
| **Interfering** | **Guar.** | **Typ.** | **Guar.** | **Typ.** | **Guar.** | **Typ.** |
| **APTc1** | 4,5 | **2,5** | 7,5 | **4,0** | 12,0 | **10,5** |
| **APTc2** | 7,5 | **4,0** | 12,0 | **10,5** | 16,0 | **7,0** |
| **APTc3** | 12,0 | **10,5** | 16,0 | **7,0** | n.a. | **10,0** |

## A.3.4.2 Guard band vs. AP to AP minimum distance

Clause A.3.2 estimates the guard band on the basis of a AP to AP minimum distance equals to 200 m.

Figure A.5 aims at providing some sensitivity of the guard band requirements in case that the minimum distance ranges from 50 m to 500 m. The case that is exemplified is, for the 42 GHz band, the one in which one (victim) APT is class 1 and the other (interfering) is class 2.

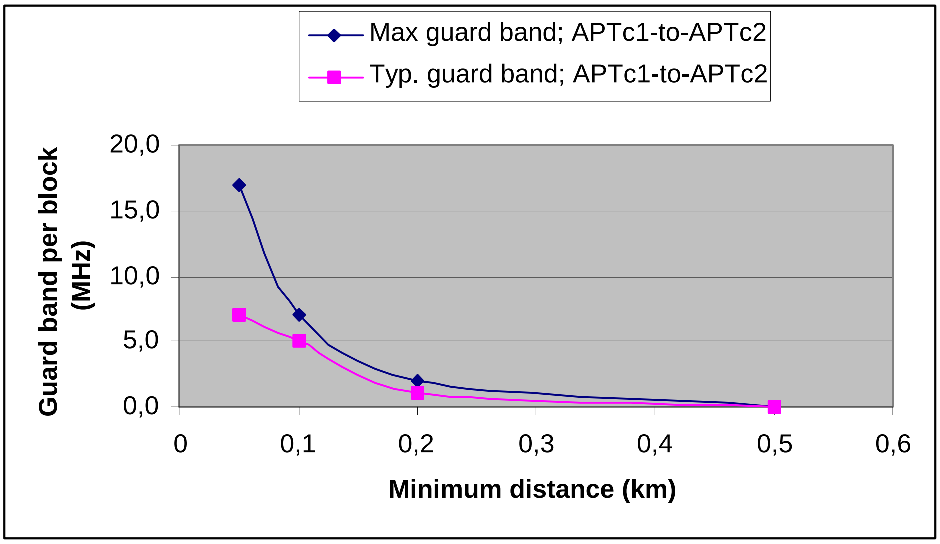



**Figure A.5: Guard band vs. AP-AP minimum distance**

Note that the guard band requirement is strongly impacted by the minimum distance: in respect to the 200 m cases, at 50 m the guard band can increase up to 10 times, vice versa at 500 m it can decrease down to 10 times or even to become zero.

# Annex B (informative): The Interference Scenario Occurrence Probability (ISOP) method [based on ERC/Report 99]

The ERC Report 99 [16] evaluates the guard band requirement on the basis of the ISOP (Interference Scenario Occurrence Probability) method, which is relevant to the interference probability that is expected in scenarios where the interference depends on the random locations of both the ATs and the APTs.

In several cases unacceptable interference occurs when the ATs are placed only in certain areas of a cell or sector. The Interference Area (IA) is the size of this area relative to the total cell or sector area.

The ISOP is defined as the probability that an operator places at least one terminal in the IA. The ISOP is related to the number of terminals deployed by the operator, and possibly to the cell planning methodology (number of channels, frequency reuse, mutual sector sizes and angles of interference and victim systems). The ISOP method evaluates the guard band required in order to meet an interference probability lower than a certain value.

In summary, the procedure used by the ERC Report 99 [16], for the estimation of the guard band, is as follows:

- Define the interference reference model:

    1) According to the defined model, evaluate the ISOP. It is a function of the interference area, #of terminals, #of channels/sector, etc.

    2) Define the ISOP requirement. The analysis assumes as acceptable an ISOP requirement equal to 1 %.

    3) From the estimated interference area, find the minimum victim to interference distance corresponding to the 1 % ISOP target.

    4) From the estimated minimum distance and according to the assumed system parameters, evaluate the interference level.

    5) From the calculated interference level and according to the carrier to interference requirement (e.g. the one which gives 1 dB degradation @$10E^{-6}$), evaluate the Net Filter Discrimination (NFD) requirement.

    6) From the above calculated NFD requirement and according to corresponding table reported in annex A, finally evaluate the guard band required for a reasonable interference free uncoordinated deployment.

# The interference reference model

In this clause we evaluate the occurrence probability of the hub to terminal scenario, drawing a possible reference model as the one shown in figure B.1.

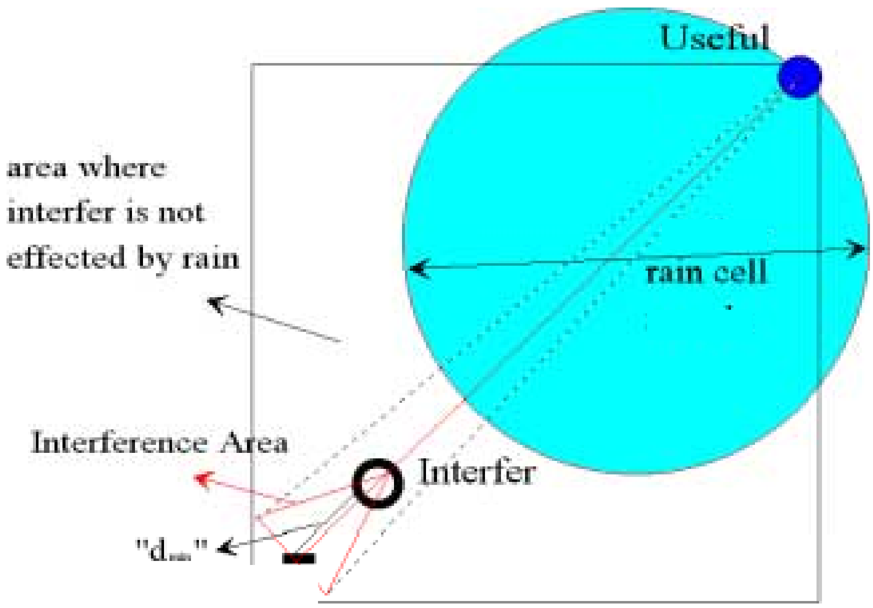



**Figure B.1: Interference scenario reference model**

The rain cell has been placed (worst case) in such a way that the circumference is centred along the sector diagonal and tangent to the sector corner where the "useful" AP is located.

Note that the typical rain cell diameter Dc (2,6 km) can be evaluated as a function of the rainfall rate R(mm/h), according to ITU-R Recommendation P.452-10, appendix 3, annex 1 [32].

$$Dc = 3{,}3 \times R(mm/h)^{-0{,}08} \quad (B.1)$$

In such a model, there is an area inside the sector where the interference is only lightly affected by the rain attenuation, while the useful signal is strongly affected by it. This is the worst situation and the one on which we will concentrate as it is the one where interference in terms of insufficient C/I is likely to occur (instead, when C and I are equally attenuated, the C/I is preserved). A certain rain correlation factor could also be accounted, as shown in annex C.

The Interference Area (IA) is the triangle with the summit in the interfering hub location and the apex angle approximated as the 3 dB terminal antenna beamwidth angle.

The probability of the above hub to terminal interference scenario is evaluated as follows:

$$ISOP = (1- (1-P1)^{Nt}) \times P2 \times P3 \quad (B.2)$$

where:

- P1 is the probability of having a terminal inside the Interference Area. In practice P1 is the ratio between IA, defined as the area of the triangle (Area_triang) of height "dmin" and apex angle (θ), and the whole sector area (Area_sect);
- $1- (1-P1)^{Nt}$ is the probability that at least one terminal falls into the interference area when there are Nt terminal stations (ATs) per sector per operators;
- P2 is the probability that the interfering hub lies in the "rain free" area of the sector. The area strongly affected by attenuation is instead defined as "Area_rain";

- P3 is related to the mutual cell planning deployment carried out by the neighbouring operators. It is the probability that one interfering Hub lies in the useful sector and uses a channel, which is adjacent and co-polar to the victim channel. P3 depends on the number of available channels per operators and on the relative coverage and cell planning deployments. P3 equals to [2/(Reuse_fact X Nch)] X $[(db/da)^{2/Ns}]$, where Reuse_fact is the sector frequency reuse factor and Nch is the number of different carriers, with single or double polarization (here defined as available channels) used in the cell planning. Ns is the number of sector per cell (for 90° sector, Ns = 4). The terms da and db are respectively the max coverage ranges achievable by the systems operated by the neighbouring operators. In the present analysis the reuse factor is assumed to be 1 (worst case) and db = da. The ISOP calculation formula is given in the ERC Report 99 [16].

# Annex C (informative): Rain cells model analysis

The simplified model above described considers the rain cells as cylindrical while in reality they behaves an exponential like decay. The documents: "The Spatial Structure of Rain and its Impact on the Design of Advanced TLC Systems"; "A Comprehensive Meteorologically Oriented Methodology for the Prediction of Wave Propagation Parameters in Telecommunication Applications Beyond 10 GHz"; "Data and Theory for a New Model of the Horizontal Structure of Rain Cells for Propagation Applications"; "The effect of precipitation on Microwave LMDS Networks - Performance Analysis Using a Physical Rain Cell Model" (see bibliography) define a physical model validated in many years of rain observations through a meteorological radar, according to which the rain is modelled by a population of circularly symmetrical, exponentially-profiled rain-cells.

The rain-cell distribution is then fitted to the local, site-specific rain statistics.

For each rain-cell, the point rain-rate R at a distance ρ [km] from the centre is given by the following expression:

$$R(\rho) = (R_M)e^{-\frac{\rho}{\rho_0}} \text{ [mm/h]} \qquad \text{(C.1)}$$

where RM is the peak rainfall intensity (at the centre of the cell), $\rho_0$ defines the cell size. The cell descriptors $\rho_0$ and RM characterize different types of rain-cells.

The path attenuation produced by each rain-cell is evaluated by integrating the specific attenuation γR [dB/km] over the path length; according to the well-known ITU-R procedure, γR can be related to the point rain rate R [mm/h] through the relation:

$$\gamma_R = kR^{\alpha} \qquad \text{(C.2)}$$

where the parameters k,α depend on frequency, polarization, and elevation angle of the radio link. The rain attenuation A [dB] along each rainy path can be calculated by integrating Equation IX along the path itself:

$$A = \int kR^{\alpha} dl = k \int R(\rho_0, R_M)^{\alpha} dl \text{ [dB]} \qquad \text{(C.3)}$$

This theory can be applied to the particular deployment described in clause A.3.1.1 (table A.3), extracting the particular exponentially profiled raincell curve providing around 20 dB attenuation (able to provide the system threshold) along a specific path length (useful path) and with $\rho_0$ exemplified as equal to 2 km. Figures C.1 and C.2 show some examples of the radio link attenuations along the useful paths (RN2-AT, the victim AT is at the corner of the sector) and along the interfering path (RN1-AT) as a function of the raincell displacement. The value of the attenuation on the interfering path, which corresponds to the maximum attenuation in the useful path, can be said as the "rain correlation factor". Considering the HIPERACCESS coverage ranges and minimum distances, estimated in table A.3 and in accordance with the results shown in figures C.1 and C.2, the typical rain correlation factor can be assumed to be 3 dB, for 32 GHz/42 GHz bands and 2 dB, for the 26 GHz/28 GHz bands.

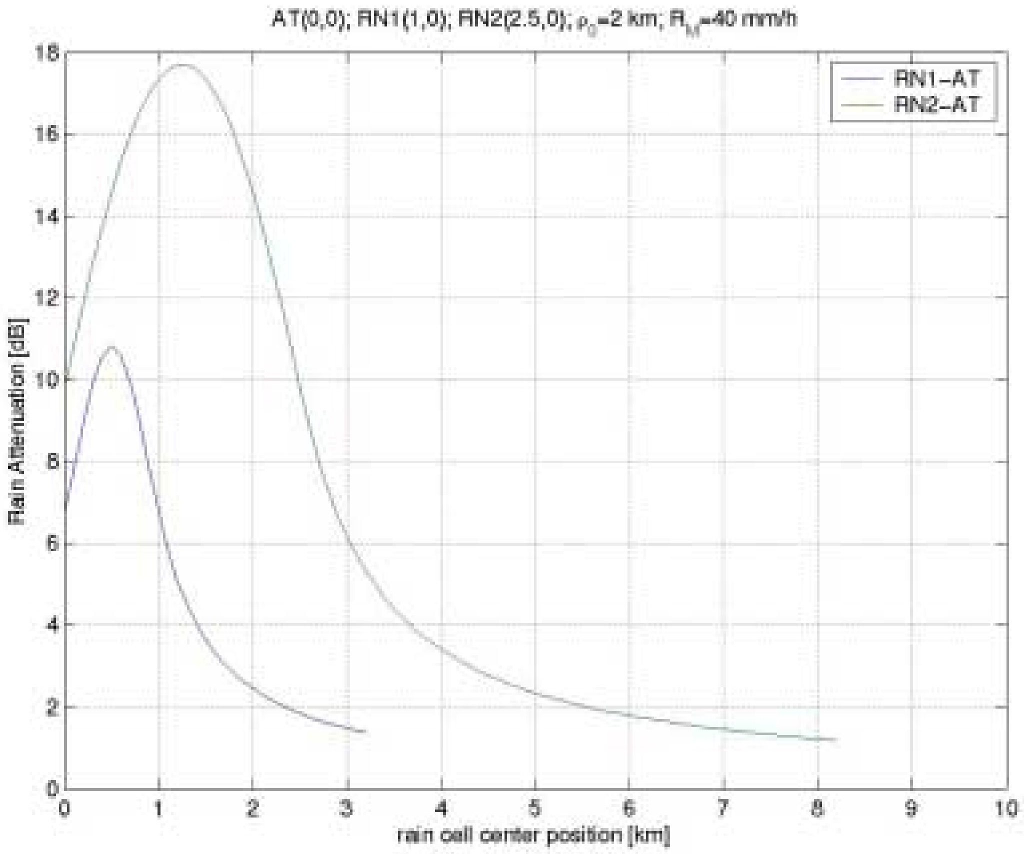



**Figure C.1: Rain attenuation vs rain-cell displacement, case 42 GHz (useful path: 2,5 km; interfering path:1 km)**

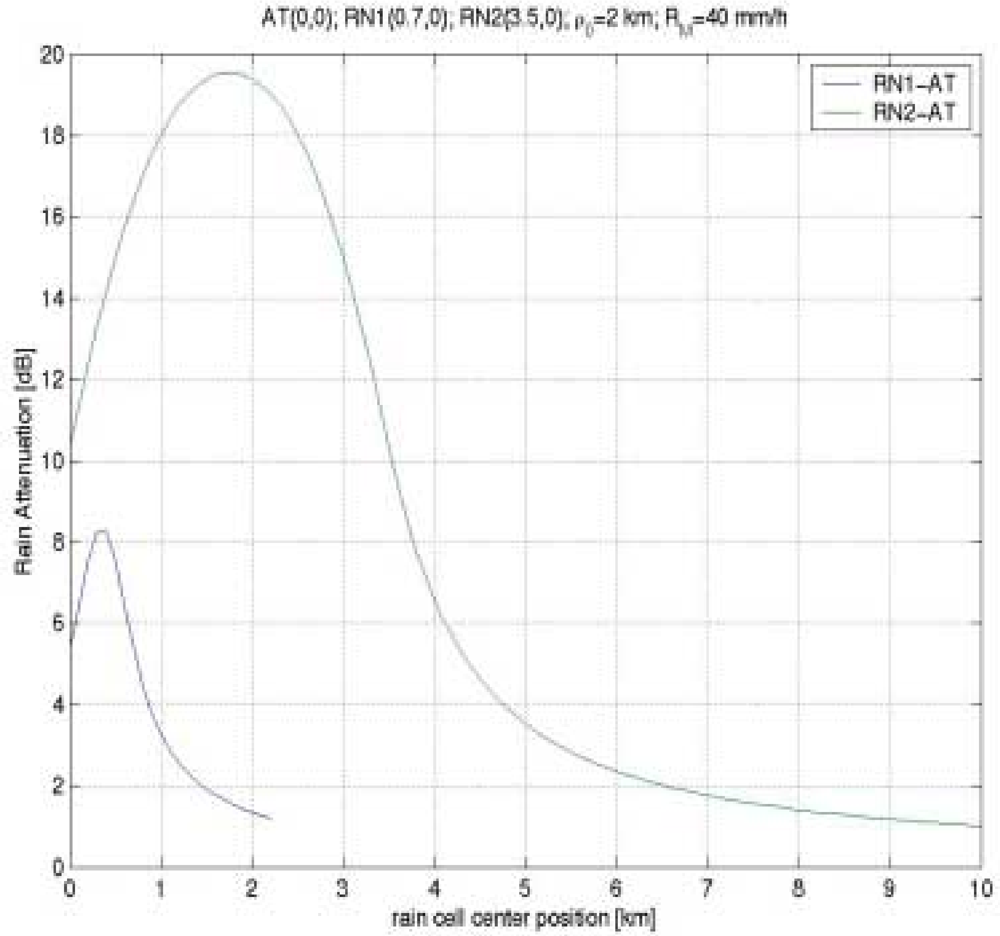



**Figure C.2: Rain attenuation Vs rain-cell displacement, case 26 GHz (useful path: 3,5 km; interfering path: 0,7 km)**

# Annex D (informative): Example of estimation of the interference rejection of the HIPERACCESS receiver in the 42 GHz band

### *Receiver interference rejection for the DL and UL interference scenarios*

The 42 GHz block edge mask (see CEPT/ECC Recommendation 01-04 [14]) limits the out-of-band emission, which corresponds to the in-band interference expected by a HIPERACCESS receiver, displaced at a certain distance from block edge.

The "downlink interference block edge masks", as seen at the AT receiver antenna connector, can be derived from the block edge mask and evaluated according to the free space loss criterion expressed as follows:

[Tx DL block edge mask] + Gt – 92,4 dB – 20 X log (F) – 20 X log (dmin) – Atm – Kc (D.1)

The "uplink Interference block edge masks", as seen at the APT receiver antenna connector, can be derived from the block edge mask and evaluated according to the free space loss criterion expressed in the following formula:

[Tx UL block edge mask] + Gn – 92,4 dB – 20 X log (F) – 20 X log (dmin) – Atm – Kc-Af D.2)

where F is the frequency of operation, hereby 42 GHz;

Gn (APT antenna) is 24 dB (APT classes 3, worst case);

Gt (AT antenna) is 37 dB;

Kc is the rain correlation factor, here assumed to be 3 dB;

dmin is the ISOP (Interference Scenario Occurrence Probability) minimum distance (see annex B);

Af is the ATPC factor, here assumed is 10 dB; and

Atm is the atmospheric absorption according to the ITU-R Recommendation P.676-5, annex 2 [30] and according to the following data:

- Pressure: 1 013 hPa, Temperature: 15° C, Water vapour: According to ITU-R Recommendation P.835-3, clause 3.1 (summer profile) [31];
- Water vapour density: related to the 0 m to 400 m antenna altitude and to the middle latitude (45°).

In figure D.1 the Tx EIRP density block edge masks, stated in [14], are translated, by using equations D.1 and D.2, into a corresponding "interference EIRP density block edge mask" as seen at the AT and APT antenna connectors. Note that the APT class 3 (worst case) is considered.

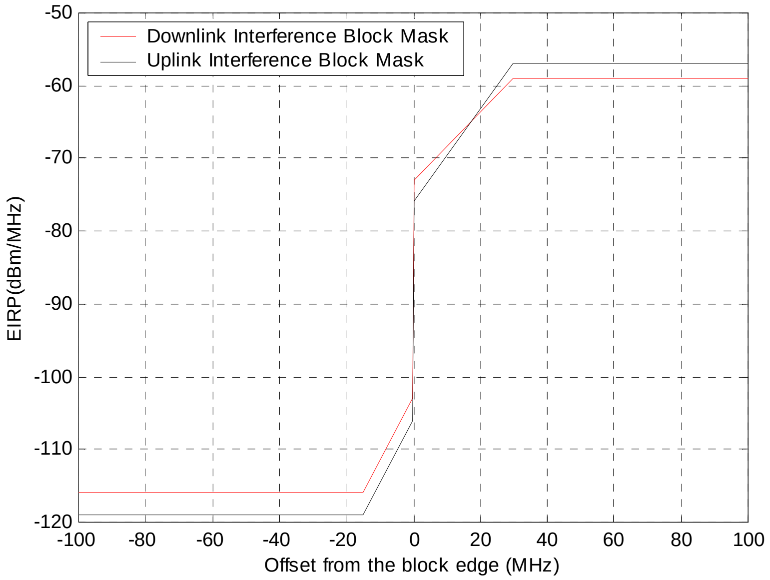



**Figure D.1: "Interference block edge masks" as seen at the Rx antenna connector**

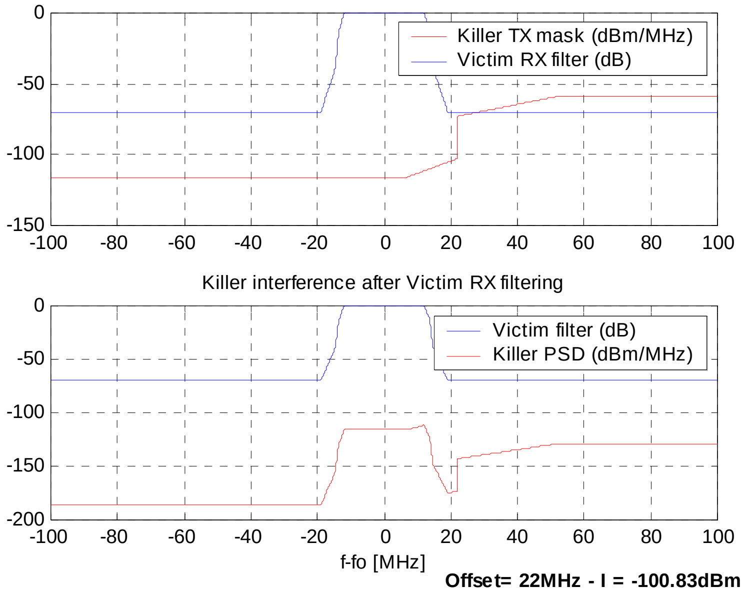



**Figure D.2: In-band interference level at 8 MHz guard band**

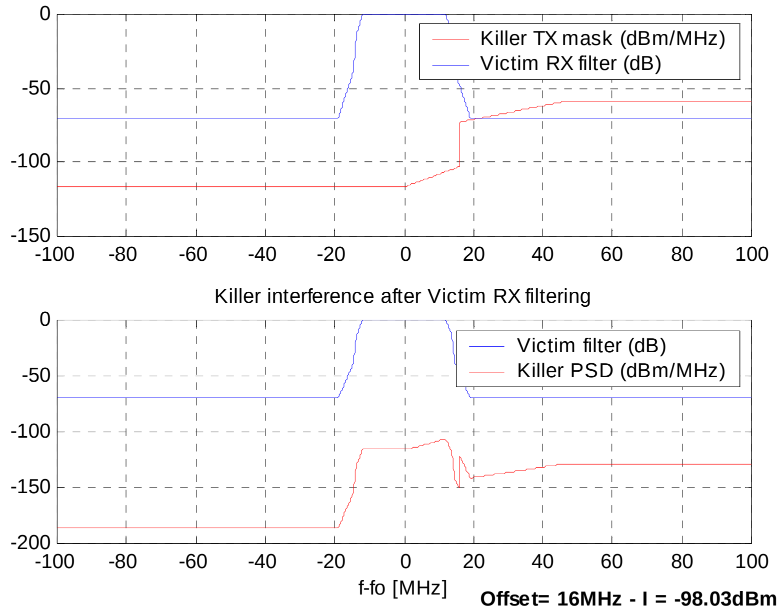



**Figure D.3: In-band interference level at 2 MHz guard band**

Figure D.2, upper side, shows the DL/UL block edge masks and the HIPERACCESS Rx filter, assumed as typical (derived from the SRRC shaping), shifted by 22 MHz (corresponding to 8 MHz guard band) from the block edge. The lower side, shows the interfering signal after Rx filtering and evaluates the resulting interference level at the AT antenna connector. This interference level is around –100 dBm, which provides a worst-case C/I = 17 dB with respect to the Rx threshold at BER $10E^{-6}$ (-83 dBm) of mode M1, well above the C/I target which is 14 dB (for 1 dB degradation).

Figure D.3 shows the DL/UL block edge masks and the HIPERACCESS Rx filter shifted by 16 MHz (corresponding to 2 MHz guard band) from the block edge. The lower side, shows the interfering signal after Rx filtering and evaluates the resulting interference level at the AT antenna connector. This interference level is around –98 dBm, which provides a worst-case C/I = 15 dB with respect to the Rx threshold at BER $10E^{-6}$ (-83 dBm) of mode M1, above the C/I target which is 14 dB (for 1 dB degradation).

### *Receiver interference rejection for the APT to APT interference scenarios*

The APT "interference block edge masks", as seen at the APT receiver antenna connector, can be derived from the downlink block edge mask and evaluated according to the free space loss criterion, expressed as follows:

[Tx DL block edge mask] + Gn – 92,4 dB – 20 X log (F) – 20 X log (dmin) – Atm – Kc (D.3)

where, F is the frequency of operation, hereby 42 GHz;

Gn (APT antenna) is 18 dB, 21 dB or 24 dB (respectively APT classes 1, 2 and 3);

Kc is the rain correlation factor, here assumed to be 0 dB;

$d_{min}$ is assumed to be 0,2 km;

Atm is the atmospheric absorption according to the ITU-R Recommendation P.676-5, annex 2 [30] and according to the following data:

- Pressure: 1 013 hPa, Temperature: 15° C, Water vapour: According to ITU-R Recommendation P.835-3, clause 3.1 (summer profile) [31];
- Water vapour density: related to the 0 m to 400 m antenna altitude and to the middle latitude (45°).

Figure D.4 shows the APT to APT class 1 block edge mask and the HIPERACCESS Rx filter shifted by 16 MHz (corresponding to 2 MHz guard band) from the block edge. The lower side, shows the interfering signal after Rx filtering and evaluates the resulting interference level at the AT antenna connector. This interference level is around -97 dBm, which provides a worst-case C/I = 14 dB with respect to the Rx threshold of mode M1 at BER $10E^{-6}$ (-83 dBm).

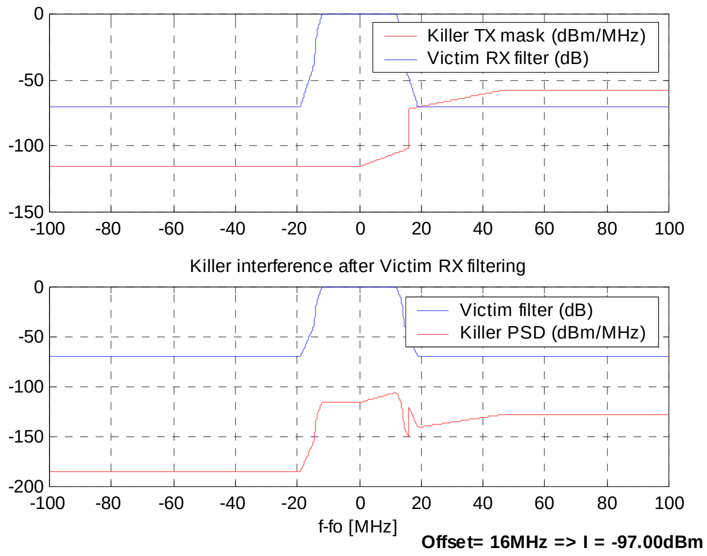



**Figure D.4: In-band interference level at 2 MHz guard band for APT class 1**

Figure D.5 shows the APT to APT class 2 block edge mask and the HIPERACCESS Rx filter shifted by 23 MHz (corresponding to 9 MHz guard band) from the block edge. The lower side, shows the interfering signal after Rx filtering and evaluates the resulting interference level at the AT antenna connector. This interference level is around -97 dBm, which provides a worst-case C/I = 14 dB with respect to the Rx threshold of mode M1 at BER $10E^{-6}$ (-83 dBm).

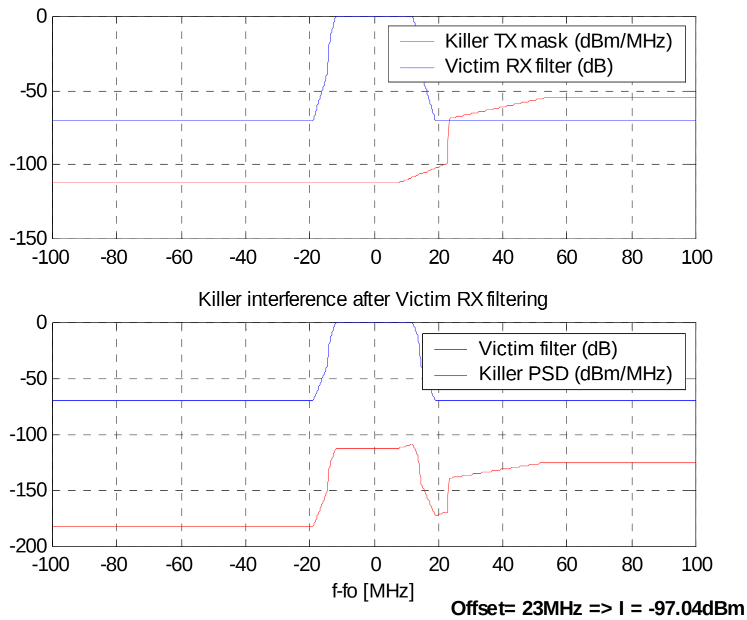



**Figure D.5: In-band interference level at 9 MHz guard band for APT class 2**

Figure D.6 shows the APT to APT class 3 block edge mask and the HIPERACCESS Rx filter shifted by 42 MHz (corresponding to 28 MHz guard band) from the block edge. The lower side, shows the interfering signal after Rx filtering and evaluates the resulting interference level at the AT antenna connector. This interference level is around -94,5 dBm, which provides a worst-case C/I = 11,5 dB with respect to the Rx threshold of mode M1 at BER $10E^{-6}$ (-83 dBm). The C/I is then below the target (14 dB). The APT class 3 would require either higher minimum distance or relaxation of the Rx threshold degradation (1,6 dB degradation instead of 1 dB at BER $10^{-6}$).

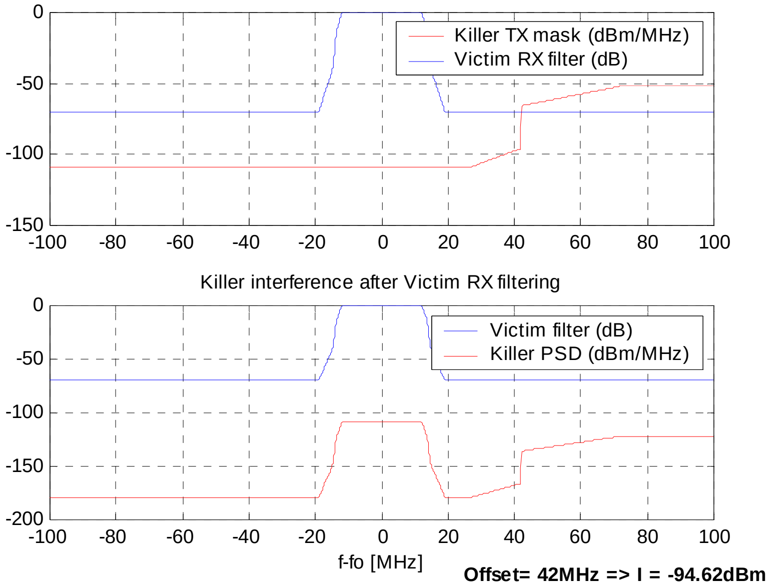



**Figure D.6: In-band interference level at 28 MHz guard band for APT class 3**

# Annex E (informative): Summary of the HIPERACCESS parameters required for the coexistence analysis

The HIPERACCESS parameters required for the coexistence analysis are recapitulated from the main body of the physical layer technical specification and summarized below.

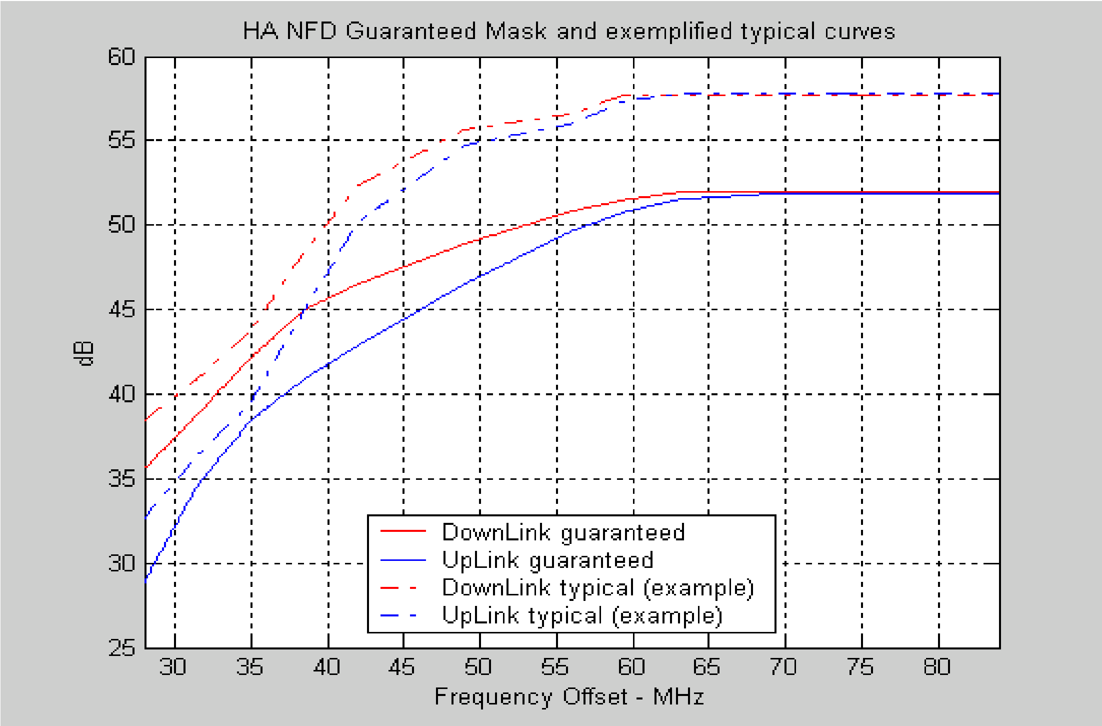



**Figure E.1: NFD guaranteed mask and exemplified typical curves**

**Table E.1: AT antenna and Tx power parameters**

| Frequency band | Nominal Antenna Gain | Typical Beamwidth (°) | AT Tx maximum output power | AT Max EIRP |
|---|---|---|---|---|
| 42 GHz | 37 dBi | 2 | +14 dBm | +54 dBmi |
| 32 GHz | 35,5 dBi | 2,6 | +14 dBm | +52,5 dBmi |
| 28 GHz | 34,5 dBi | 3,1 | +14 dBm | +51,5 dBmi |
| 26 GHz | 33,5 dBi | 3,3 | +14 dBm | +50,5 dBmi |

**Table E.2: APT antenna and Tx power parameters**

| APT class | Nominal Antenna gain | Typical Beamwidth (°) | Tx maximum output power | APT Max EIRP |
|---|---|---|---|---|
| 1 | 18 dBi | 90 | +15 dBm | +36 dBmi |
| 2 | 21 dBi | 45 | +15 dBm | +39 dBmi |
| 3 | 24 dBi | 22,5 | +15 dBm | +42 dBmi |

**Table E.3: C/N, Rx threshold and C/I for 1 dB degradation for BER = $10^{-6}$**

| PHY modes | C/N@BER $10E^{-6}$ | C/I@1 dB degradation | Rx Threshold at BER = $10E^{-6}$ | | |
|---|---|---|---|---|---|
| | | | 26/28 GHz dBm | 32 GHz dBm | 42 GHz dBm |
| 4QAM, CC2/3 | 8 | 14 | -85,0 | -84,0 | -83,0 |
| 4QAM | 12 | 18 | -81,0 | -80,0 | -79,0 |
| 16QAM, CC7/8 | 18 | 24 | -75,0 | -74,0 | -73,0 |
| 16QAM | 20 | 26 | -73,0 | -72,0 | -71,0 |
| 64QAM, CC5/6 | 25 | 31 | -68,0 | -67,0 | -66,0 |
| 64QAM | 27 | 33 | -66,0 | -65,0 | -64,0 |

**Table E.4: Deployment parameters**

| | Number of ATs/carrier | Frequency block size | Worst case frequency reuse factor |
|---|---|---|---|
| 42 GHz | 80 | 4 X 28 MHz (8 channel configurations with H/V pol.) | 1 |
| 32 GHz | 80 | 2 X 28 MHz (4 channel configurations with H/V pol.) | 1 |
| 28 GHz | 80 | 2 X 28 MHz (4 channel configurations with H/V pol.) | 1 |
| 26 GHz | 80 | 2 X 28 MHz (4 channel configurations with H/V pol.) | 1 |

# Annex F (informative): RF-Channel Plans, Example

# F.1 RF virtual vhannel plan in MWS (42 GHz) band for FDD

This example corresponds to the extreme scenario in which a National Administration allocates the entire 42 GHz frequency band to the HIPERACCESS system deployments. When all operators operates HIPERACCESS FDD systems by using the APT class 1, no guard bands are required among the neighbour frequency blocks (as deduced from the annex A analysis), and all the 28 MHz channels can be displaced one near to the others. This scenario can generate a virtual HIPERACCESS channel plan, described in this clause.

## F.1.1 40,5 GHz to 43,5 GHz band

The radio frequency slots for separations of 28 MHz shall be derived as follows:

Let:

fr be the reference frequency of 42 000 MHz;

fn be the centre frequency (MHz) of the radio-frequency slot in the lower half of the band;

fn' be the centre frequency (MHz) of the radio-frequency slot in the upper half of the band;

Duplex spacing = 1 500 MHz;

Centre gap = 16 MHz;

then the frequencies (MHz) of individual slots are expressed by the following relationships:

| | | |
|---|---|---|
| lower half of the band: | fn = fr – 1 506 + 28 X n | where n = 1, 2, 3, … 53 |
| upper half of the band: | fn' = fr – 6 + 28 X n | |

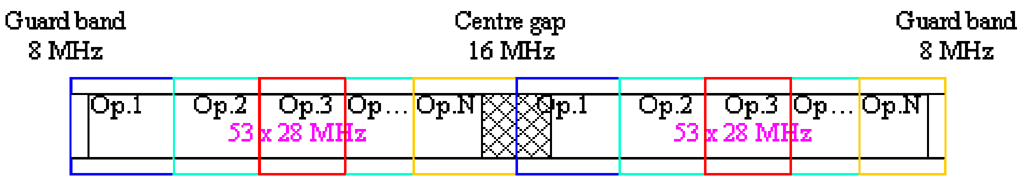



**Figure F.1: Occupied spectrum: 40,5 GHz to 43,5 GHz band**

## F.1.2 40,5 GHz to 42,5 GHz band

The radio frequency slots for separations of 28 MHz shall be derived as follows:

Let:

- fr be the reference frequency of 41 500 MHz;
- fn be the centre frequency (MHz) of the radio-frequency slot in the lower half of the band;
- fn' be the centre frequency (MHz) of the radio-frequency slot in the upper half of the band;

- Duplex spacing = 1 000 MHz;
- Centre gap = 20 MHz;

then the frequencies (MHz) of individual slots are expressed by the following relationships:

| | | |
|---|---|---|
| lower half of the band: | fn = fr – 1 004 + 28 X n | where n = 1, 2, 3, … 35 |
| upper half of the band: | fn' = fr – 4 + 28 X n | |

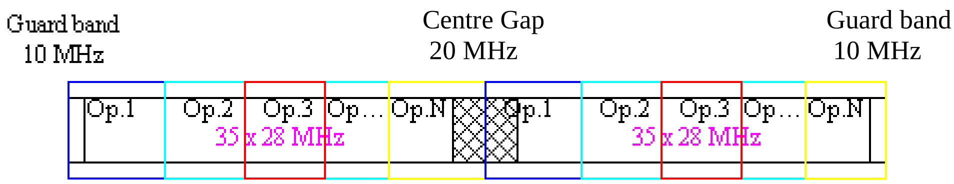



**Figure F.2: Occupied spectrum: 40,5 GHz to 42,5 GHz band**

# F.2 RF virtual channel plan in MWS (42 GHz) band for TDD

In the case where local regulatory considerations do not dictate a block based arrangement, TDD can use the default 1 MHz slot plan according to CEPT/ERC recommendations.

# F.3 Example of heterogeneous system deployment

Figure F.3 exemplifies heterogeneous frequency block allocations relevant to operators operating various system deployments in case on no downlink power control is employed. In each case a different guard band requirement applies.

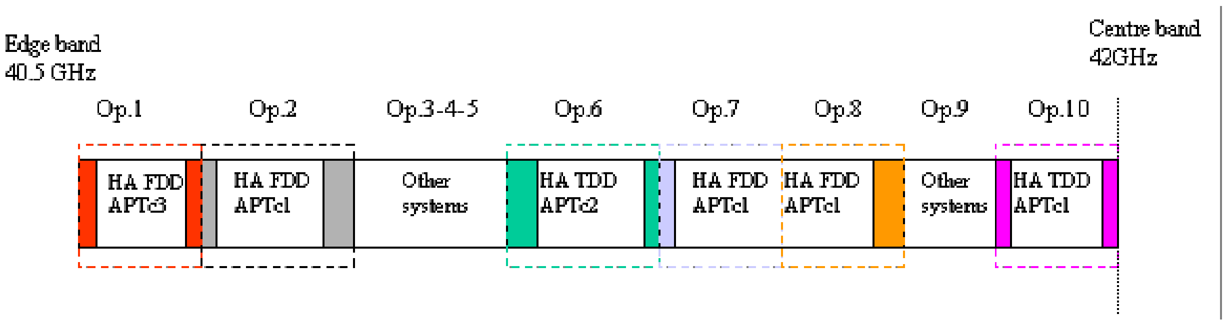



**Figure F.3: Example of heterogeneous system deployments**

- Operator 1 deploys a HIPERACCESS system with FDD scheme and APT class 3. The maximum guard band required at the left side shall be 21 MHz, in accordance with table A.1. The maximum guard band required at the right side shall be 3,5 MHz, in accordance with table A.13, in case that the National Administration allows the co-operative deployment otherwise it becomes again 21 MHz, in accordance with table A.1.
- Operator 2 deploys a HIPERACCESS system with FDD scheme and APT class 1. The maximum guard band required at the left side shall be 3,5 MHz, in accordance with table A.13, in case that the National Administration allows the co-operative deployment otherwise it becomes 8 MHz, in accordance with table A.1. The maximum guard band required at the right side shall be again 8 MHz, in accordance with table A.1.

- Operator 6 deploys a HIPERACCESS system with TDD scheme and APT class 2. The maximum guard band required at the left side shall be 13 MHz, in accordance with table A.1. The maximum guard band required at the right side shall be 2 MHz, in accordance with table A.13, in case that the National Administration allows the co-operative deployment otherwise it becomes again 13 MHz, in accordance with table A.1.
- Operator 7 deploys a HIPERACCESS system with FDD scheme and APT class 1. The maximum guard band required at the left side shall be 2 MHz, in accordance with table A.13, in case that the National Administration allows the co-operative deployment otherwise it becomes 8 MHz, in accordance with table A.1. The maximum guard band required at the right side shall be 0 MHz, in accordance with table A.6.
- Operator 8 deploys a HIPERACCESS system with FDD scheme and APT class 1. The maximum guard band required at the left side shall be 0 MHz, in accordance with table A.6, in case that the National Administration allows the co-operative deployment otherwise it becomes 8 MHz, in accordance with table A.1. The maximum guard band required at the right side shall be 8 MHz, in accordance with table A.1.
- Operator 10 deploys a HIPERACCESS system with TDD scheme and APT class 1. The maximum guard band required at the left side shall be 8 MHz, in accordance with table A.1. The maximum guard band required at the right side shall be again 8 MHz, in accordance with table A.1.

# Annex G (informative): Receiver parameters

## G.1 Noise Figures

**Reference Noise Figure (NF) and RF filter loss figures**

| Frequency band [GHz] | RF filtering loss, typical (over temp.) [dB] | Rx LNA NF, typical (over temp.) [dB] | Overall Rx NF, typical (over temp.) [dB] |
|---|---|---|---|
| 26 and 28 | 2,0 (2,5) | 6,0 (7,0) | 8,0 (9,5) |
| 32 | 2,5 (3,5) | 6,0 (7,0) | 8,5 (10,0) |
| 42 | 2,5 (3,5) | 7,0 (8,0) | 9,5 (11,5) |

## G.2 C/N values and the implementation losses

**System implementation losses**

**SET-1: Outer code RS carrying 4 PDUs**

| PHY modes | Th. C/N AWGN ($10^{-6}$) | Tx. loss (EVM) | Equaliz. loss $C_1/C_2$ | Rx-impl. loss (incl. Synch.-loss) | Total C/N loss in dB $C_0$ | $C_1/C_2$ |
|---|---|---|---|---|---|---|
| 4QAM 2/3 | 6 | 0,5 | 1 | 1,5 | 2 | 3 |
| 4QAM | 10 | 0,5 | 1 | 1,5 | 2 | 3 |
| 16QAM7/8 | 15 | 1 | 1 | 2 | 3 | 4 |
| 64QAM5/6 | 21 | 1,5 | 1 | 2,5 | 4 | 5 |

For BER = $10E^{-11}$ the following additional gaps should be considered:

| PHY modes | Additional gaps for BER = $10E^{-11}$ |
|---|---|
| 4QAM 2/3 | 1 |
| 4QAM | 1 |
| 16QAM7/8 | 1 |
| 64QAM5/6 | 1 |

**SET-2: Outer code RS carrying 4 PDUs**

| PHY modes | C/N AWGN ($10^{-6}$) | Tx. loss (EVM) | Equalization loss $C_1/C_2$ | Rx-impl. loss (incl. synch. losses) | Total C/N loss in dB $C_0$ | $C_1/C_2$ |
|---|---|---|---|---|---|---|
| 4QAM2/3 | 6 | 0,5 | 1 | 1,5 | 2 | 3 |
| 4QAM | 10 | 0,5 | 1 | 1,5 | 2 | 3 |
| 16QAM | 17 | 1 | 1 | 2 | 3 | 4 |
| 64QAM | 23 | 1,5 | 1 | 3 | 4 | 5 |

For BER = $10E^{-11}$ the following additional Gaps should be considered:

| PHY modes | Additional gaps for BER = $10E^{-11}$ |
|---|---|
| 4QAM 2/3 | 1 |
| 4QAM | 1 |
| 16QAM | 1 |
| 64QAM | 2 |

Note that the receiver sensitivity figures given in clause 5.6.2 are valid for the given carrier frequencies. However, for other frequencies which are not mentioned in this clause the nearest carrier frequency figures might be considered.

# G.3 Rx dynamic range calculation

**Example of deployment scenario:**

| Parameters | 43,5 GHz | 32 GHz |
|---|---|---|
| Maximum antenna gains (Tx + Rx) | 55 dBi | 53,5 dBi |
| Maximum Output power | 15 dBm | 15 dBm |
| Minimum Input Threshold | -83 dBm | -83 dB |
| Min/Max distance AP-AT Ratio | 50 | 50 |
| Amplitude spreading due to Min-Max distance: 20 $\log_{10}(50)$ | 34 dB | 34 dB |
| Rain zone | K (42 mm/h) | K (42 mm/h) |
| Link Availability | 99,985 % | 99,99 % |
| Resulting fade margins | 23 dB | 21 dB |
| Path loss | 133 dB | 131 dB |
| Required system gain | 101 dB | 101 dB |
| Actual System Gain | -98 dB | -99 dB |

- **Receiver dynamic for AT**
  - With no DL Power control: 57 dB. We can approximate it to 60 dB.
  - With DL Power control: 48 dB to 54 dB.
- **Receiver dynamic for APT:** 30 dB (this dynamic shall be available on an AT basis).

# Annex H (informative): Recommendations on the PHY DLC interface

As long as the interoperability is guaranteed, the exact implementation of this interface is a manufacture design. Furthermore, by analyzing the signalling exchanges between the PHY and DLC interfaces, it may allow to make a cross-check between these two layers.

Figure H.1 shows the block-diagram of this interface in the AP and in the AT. All messaging between the PHY and DLC layers in the AP and in the AT are listed in tables H.1, H.2, H.3 and H.4.

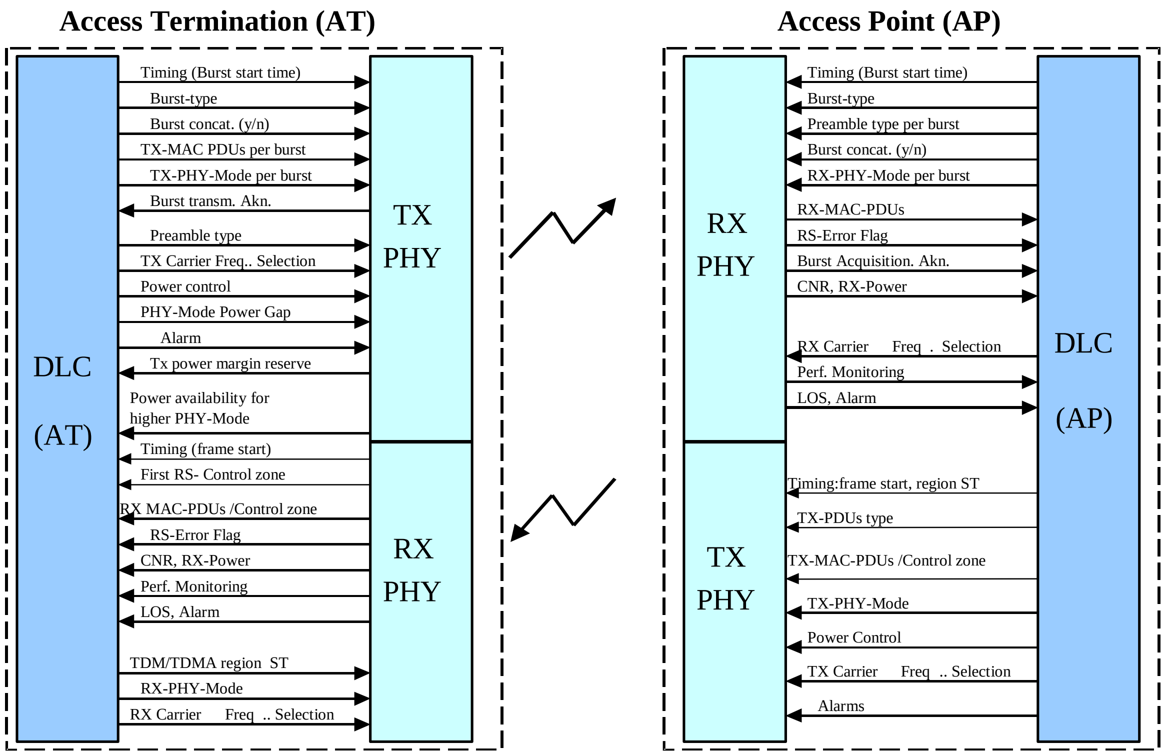



**Figure H.1: Interface between PHY and DLC**

# H.1 Interfaces in the Access Point (AP)

## Transmitter, Tx side:

**Table H.1: Interface between DLC and PHY in the AP, transmitter side**

| Signals/Messages | Detailed parameters |
|---|---|
| **Transmission side** | |
| Timing | Start of a frame and Start time of TDM or TDMA PHY mode regions |
| PDU-Type | Transmit Long MAC PDUs of 54 bytes or control zone bytes |
| Tx MAC PDUs /Control zone bytes | MAC PDUs bytes or control zone bytes to be transmitted per TDM/TDMA Phy mode region |
| Tx PHY mode | PHY mode for each TDM or TDMA region |
| Power control | Relative power control signal |
| Tx Carrier Freq. Select | Selection of the Tx carrier frequency, load leveling |
| Alarm | Alarm from DLC for stropping the transmission in the PHY |

### Receiver, Rx side:

**Table H.2: Interface between DLC and PHY in the AP, receiver side**

| Signals/Messages | Detailed parameters |
|---|---|
| **Reception side** | |
| Timing | Time to start to detect a burst |
| Burst-Type | Long burst of n X 55 MAC PDUs-bytes or short signalling burst carrying 12 bytes |
| Preamble type | 16 or 32 symbols |
| Burst concatenation | Burst concatenation: Yes or not |
| Rx PHY mode | PHY mode for each UL burst |
| Rx Carrier Freq.Select | Selection of the Rx carrier frequency, load leveling |
| Rx MAC PDUs | Received n X 55 long MAC PDUs bytes or short signalling MAC PDU bytes |
| RS-error flag | Error flag per each RS decoded block |
| Burst acquisition Akn. | Acknowledgment for a successful acquisition of a burst |
| CNR, Rx Power | Measured CNR and Rx power |
| Perf. Monitoring | Information collected by the PHY layer about link quality following ITU-T Recommendations G.821 [11], G.826 [12] and M.2100 Series [26]. |
| Alarm, LOS | Alarm for anomaly from Rx PHY to DLC or Los of synchronization signalling |

# H.2 Interfaces in the Access Termination (AT)

### Transmitter, Tx side:

**Table H.3: Interface between DLC and PHY in the AT, transmitter side**

| Signals/Messages | Detailed parameters |
|---|---|
| **Transmission side** | |
| Timing | Start time for the transmission of a burst |
| Burst-Type | Long burst carrying n X 55 long MAC PDUs bytes or short burst carrying 12 short signalling MAC PDU bytes |
| Burst concatenation | Burst concatenation: Yes or not |
| Tx MAC PDUs | Short or long MAC PDUs to be transmitted per burst |
| Tx PHY mode | PHY mode for each transmitted burst |
| Power control | Relative power control signal |
| Tx Carrier Freq. Select | Selection of the Tx carrier frequency, load leveling |
| Preamble type | 16 or 32 symbols |
| PHY mode power Gap | Automatic power correction/adaptation in case of change of PHY mode |
| Burst transm. Akn. | Acknowledgment for the successful transmission of a burst |
| Tx power margin reserve | The actual Tx power reserve available |
| Power availability for changing to higher PHY mode | The indication from the PHY layer to the DLC layer to notify the amount of enough available power in order switch to a more efficient PHY mode |
| Alarm | Alarm from DLC for stopping the PHY transmission |

## Receiver, Rx side:

**Table H.4: Interface between DLC and PHY in the AT, receiver side**

| Signals/Messages | Detailed parameters |
|---|---|
| **Reception side** | |
| Timing | Detection of the beginning of a frame: Frame start time |
| First RS-Control zone | First 30 bytes of control zone |
| Rx MAC PDUs /Control zone bytes | Received n X long MAC PDUs of 55 bytes or control zone bytes |
| RS-error flag | Error flag per each RS decoded block |
| CNR, Rx Power | Measured CNR and RX power |
| Perf. Monitoring | Information collected by the PHY layer about link quality following ITU-T Recommendations G.821 [11], G.826 [12] and M.2100 Series [26] |
| Alarm, LOS | Alarm for anomaly from Rx PHY to DLC or Los of synchronization signalling |
| TDM/TDMA region ST | Start time for detecting each TDM or TDMA PHY mode region |
| Rx PHY mode | PHY mode for each DL TDM or TDMA PHY mode region |
| Rx Carrier Freq.Select | Selection of the Rx carrier frequency, load leveling |

# Annex I (informative): Performance monitoring parameters

For the network management purposes, the PHY layer should provide means for performance monitoring and change of PHY parameters.

For performance monitoring purposes two standards will be applied:

- Radio link quality monitoring: ITU-T Recommendations G.826 [12], G.821 [11], G.827 [15] and M.2100 Series [26].
- Logical link quality monitoring: In case of ATM: ITU-T Recommendation I.356 (see bibliography).

For both quality monitoring purposes, the PHY layer should provide the following parameters:

- ES Bit errors per seconds.
- SES Severely Errorred Seconds (defined as 1 s period with al least 30 % of erroneous block).
- BBE Background Block Error.
- SEP Severely Errored Period (Number of consecutive SES periods).
- OI Outage Intensity.
- C/N.
- Bit error rate/Packet error rate.
- Tx and Rx Power levels.
- Tx power margin reserve
- Round trip delay.
- Alarms.
- etc.

However, for changing the PHY parameters from the network management side, the PHY layer should support the following:

- Different channel raster: n X 28 MHz (load levelling)
- Two different PHY modes sets.

# Annex J (informative): Bibliography

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# List of figures

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# History

| Document history | | |
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| V1.1.1 | April 2002 | Publication |
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