ETSI TS 102 177 V1.5.1 (2010-05)

Technical Specification

Broadband Radio Access Networks (BRAN);
HiperMAN;
Physical (PHY) layer

Reference

RTS/BRAN-0040001r6

Keywords

access, broadband, FWA, HiperMAN, layer 1,
MAN, nomadic, radio

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Foreword

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

The present document describes the physical layer specifications for High PERformance Radio Metropolitan Area Network (HiperMAN). Separate ETSI documents provide details on the system overview, Data Link Control (DLC) layer, Convergence Layers (CL) and conformance testing requirements for HiperMAN.

With permission of IEEE® (on file as BRAN43d016), portions of the present document are excerpted from IEEE Standards [2] and [3].

1 Scope

The present document specifies the HiperMAN air interface with the specification layer 1 (physical layer), which can be used to provide Fixed applications, in frequencies below 11 GHz, and Nomadic and converged Fixed-Nomadic applications, in frequencies below 6 GHz. The present document follows the ISO-OSI model. HiperMAN is confined only to the radio subsystems 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 sub-system.

The scope of the present document is as follows:

- It gives a description of the physical layer for HiperMAN systems.
- It specifies the transmission scheme in order to allow interoperability between equipment developed by different manufacturers. This is achieved by describing scrambling, channel coding, modulation, framing, control mechanisms, and power control to assist in radio resource management.
- It does cover the receiver and transmitter performance requirements which are specific for HiperMAN systems.
- Some information clauses and annexes describe parameters and system models to assist in preparing conformance, interoperability and coexistence specifications.

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

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2.1 Normative references

The following referenced documents are necessary for the application of the present document.

[1] ETSI TS 102 178: "Broadband Radio Access Networks (BRAN); HiperMAN; Data Link Control (DLC) layer".

[2] IEEE 802.16-2004: "IEEE Standard for Local and Metropolitan Area Networks - Part 16: Air Interface for Fixed Broadband Wireless Access Systems".

[3] IEEE 802.16e-2005: "IEEE Standard for Local and metropolitan area networks - Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems - Amendment 2: Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands and Corrigendum 1".

[4] Directive 1999/5/EC of the European Parliament and of the Council of 9 March 1999 on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity (R&TTE Directive).

[5] IEEE Std 802.16™-2009: "IEEE Standard for Local and metropolitan area networks Part 16: Air Interface for Broadband Wireless Access Systems.

2.2 Informative references

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area**.**

[i.1] Alamouti, S.M.: "A Simple Transmit Diversity Technique for Wireless Communications", IEEE journal on select areas in communications, Vol.16, No. 8, pages 1451-1458, October 1998.

3 Definitions, symbols and abbreviations

3.1 Definitions

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

Base Station (BS): generalized equipment consisting of one or more Base Station Controllers and one or more Base Station transceivers

channel coding: sequence composed of three steps; randomizer, forward error correction and interleaving

DL-MAP: structured data sequence that defined the mapping of the DL

DownLink (DL): direction from BS to SS

frequency offset index: index number identifying a particular carrier in an OFDM signal

NOTE: Frequency offset indices may be positive or negative and are counted relative to the DC carrier.

full duplex: equipment that is capable of transmitting and receiving 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 that cannot transmit and receive at the same time

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

Receive-Transmit Transition Gap (RTG): time to switch from receive to transmit at the BS

Subscriber Station (SS): generalized equipment consisting of a Subscriber Station Controller and Subscriber Station Transceiver

Transmit-Receive Transition Gap (TTG): time to switch from transmit to receive at the BS

UL MAP: MAC message scheduling UL bursts

UpLink (UL): direction from SS to BS

3.2 Symbols

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

BW	Nominal channel bandwidth (MHz)
F_{sa}	Sampling frequency (MHz)
N_{cbps}	Number of coded bits per OFDM symbol (on allocated subchannels)
N_{FFT}	Nominal size of the FFT operator
N_{used}	Number of carriers used to transport either data or pilots within a single OFDM symbol
R_{os}	BW over sampling ratio
T_b	Useful OFDM symbol time (s)
T_F	Frame duration (ms)

T_g	OFDM symbol guard time or CP time (s)
T_s	OFDM symbol time (s)
α_{avg}	Channel measurement averaging constant
Δf	Carrier spacing (Hz)

3.3 Abbreviations

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

AAS	Adaptive Antenna System
AWGN	Average White Gaussian Noise
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
BS	Base Station
BSID	Base Station IDentification
BW	BandWidth
CC	Convolutional Coding
CCH	Control subCHannel
CID	Connection IDentifier
CINR	Carrier to Interference Noise Ratio
CL	Convergence Layer
CNR	Carrier to Noise Ratio
CP	Cyclic Prefix
CTC	Convolutional Turbo Code
DC	Direct Current
DCD	Downlink Channel Descriptor
DIUC	Downlink Interval Usage Code
DL	DownLink
DLC	Data Link Control
DLFP	DownLink Frame Prefix
FCH	Frame Control Header
FDD	Frequency Division Duplexing
FEC	Forward Error Correction
FFT	Fast Fourier Transform
HCS	Header Check Sequence
H-FDD	Half duplex Frequency Division Duplexing
IE	Information Element
IFFT	Inverse Fast Fourier Transform
LSB	least Significant Bit
MAC	Media Access Control
MAN	Metropolitan Area Network
MSB	Most Significant Bit
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
PDU	Protocol Data Unit
PHY	PHYsical
PMP	Point-to-MultiPoint
PRBS	Pseudo Random Binary Sequence
PS	Physical Slot
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
REQ	REQuest
RF	Radio Frequency
RMS	Root Mean Square
RS	Reed-Solomon
RS-CC	Reed-Solomon / Convolutional Code
RSSI	Received Signal Strength Indicator
RTG	Receive-Transmit Transition Gap
Rx	Receive

SNR	Signal to Noise Ratio
SS	Subscriber Station
SSRTG	Subscriber Station Receive Transmit Gap
STC	Space Time Coding
TC	Transmission Convergence
TDD	Time Division Duplexing
TLV	Type Length Value
TOs	Transmission Opportunities
TTG	Transmit-receive Transition Gap
Tx	Transmit
UCD	Uplink Channel Descriptor
UIUC	Uplink Interval Usage Code
UL	UpLink
XOR	eXclusive OR

4 HiperMAN OFDM PHY

4.1 OFDM symbol description

An OFDM waveform is created by applying an Inverse-Fourier-transform to the source data. The resultant time duration is referred to as the useful symbol time T_b. A copy of the last T_g μs of the useful symbol period, termed Cyclic Prefix (CP), is prepended to enable the collection of multipath at the receiver, without loss of orthogonality between the tones. The resulting waveform is termed the symbol time T_s. Figure 1 illustrates this structure.

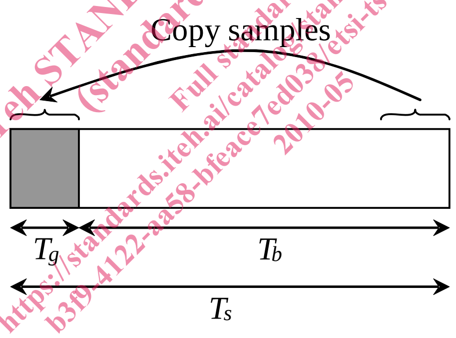

Figure 1: OFDM symbol time structure

The transmitter energy increases with the length of the CP while the receiver energy remains the same (the CP is discarded), so there is a $10\log(1-T_g/(T_b+T_g))/\log(10)$ dB loss in SNR. Using the CP, the samples required for performing the FFT at the receiver can be taken anywhere over the length of the extended symbol. This provides multipath immunity as well as a tolerance for symbol time synchronization errors.

On system initialization, the Base Station (BS) CP fraction (T_g/T_b) shall be set to a specific value for use on the Downlink (DL). Once the BS is operational the CP value shall not be changed. On initialization, the Subscriber Station (SS) shall search all possible values of CP until it finds the CP being used by the serving BS. The SS shall use the same CP values determined in DL for the UL. Changing the CP value parameter at the BS through (re)initialization forces all SS registered on that BS to re-synchronize.

In the frequency domain, each OFDM symbol is comprised of multiple carriers (see figure 2), which belong to one of three types:

- Data carriers - for data transmission.
- Pilot carriers - for channel estimation and other purposes.
- Null carriers - for guard bands and the DC carrier.

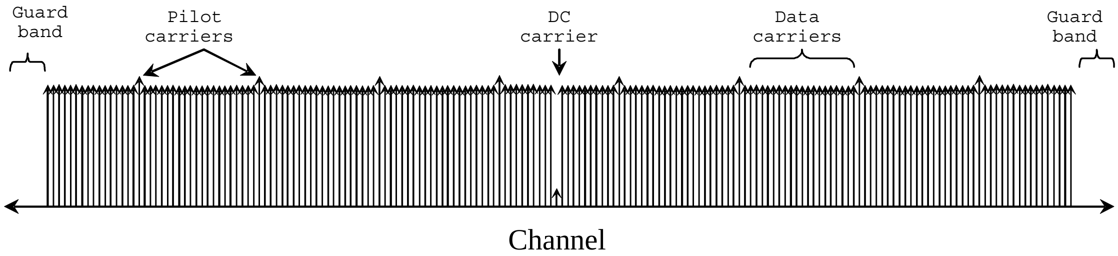

Figure 2: OFDM symbol frequency structure

4.2 Transmitted signal

Equation 1 specifies the transmitted signal voltage $s(t)$ to the antenna, as a function of time, during any OFDM symbol.

$$s(t) = \mathrm{Re}\left\{ e^{2j\pi f_c t} \sum_{\substack{k=-N_{\text{used}}/2 \\ k \neq 0}}^{k=N_{\text{used}}/2} c_k \times e^{2j\pi k\Delta f\left(t-T_g\right)} \right\} \quad (1)$$

where: t is the time elapsed since the beginning of the subject OFDM symbol, with $0 < t < T_s$.

C_k is a complex number; the data to be transmitted on the carrier whose frequency offset index is k, during the subject OFDM symbol. It specifies a point in a Quadrature Amplitude Modulation (QAM) constellation. In the case of subchannelization, C_k is zero for all unallocated.

f_c is the RF carrier frequency, being the centre frequency of the intended RF frequency channel.

k is the frequency offset index.

The parameters of the transmitted OFDM signal, which shall be used, are given in table 1.

Table 1: OFDM symbol parameters

Parameter	Value
N_{FFT}	256
N_{used}	200
T_g / T_b	1/4, 1/8, 1/16, 1/32
Frequency offset indices of guard carriers	-128, -127 to -101 +101, +102 to 127
Frequency offset indices of Pilots	-88, -63, -38, -13, 13, 38, 63, 88
Subchannel Index	Allocated frequency offset indices of carriers
0b00001	{-100:-98, -37:-35, 1:3, 64:66}
0b00010	{-38}
0b00100 0b00011	{-97:-95, -34:-32, 4:6, 67:69}
0b00101	{-94:-92, -31:-29, 7:9, 70:72}
0b00110	{13}
0b01000 0b00111	{-91:-89, -28:-26, 10:12, 73:75}
0b01001	{-87:-85, -50:-48, 14: 16, 51:53}
0b01010	{-88}
0b01100 0b01011	{-84,-82, -47:-45, 17: 19, 54:56}
0b01101	{-81:-79, -44:-42, 20:22, 57:59}
0b01110	{63}
0b10000 0b01111	{-78:-76, -41:-39, 23:25, 60:62}
0b10001	{-75:-73, -12:-10, 26:28, 89:91}
0b10010	{-13}
0b10100 0b10011	{-72:-70, -9: -7, 29:31, 92:94}
0b10101	{-69:-67, -6: -4, 32:34, 95:97}
0b10110	{38}
0b11000 0b10111	{-66:-64, -3: -1, 35:37, 98:100}
0b11001	{-62:-60, -25:-23, 39:41, 76:78}
0b11010	{-63}
0b11100 0b11011	{-59:-57, -22:-20, 42:44, 79:81}
0b11101	{-56:-54, -19:-17, 45:47, 82:84}
0b11110	{88}
0b11111	{-53:-51, -16:-14, 48:50, 85:87}
NOTE: Pilot carriers are allocated only if two or more subchannels are allocated.	

Using the parameters as specified in table 1, the following relationships shall hold.

$$F_{sa} = floor\ (R_{os} \times BW\ /\ 8\ 000) \times 8\ 000$$

$$\Delta f = R_{os} \times BW / N_{FFT}$$

$$T_b = 1 / \Delta f$$

$$T_g = \left(T_g / T_b \right) \times T_b$$

$$T_s = T_b + T_g$$

$$T_{sa} = 1 / F_{sa}$$

$$F_{sa} = R_{os} \times BW$$

4.3 Channel coding

Channel coding is composed of three steps: randomization, forward error correction, and interleaving. They shall be applied in this order at transmission. The complementary operations shall be applied in reverse order at reception.

4.3.1 Randomization

Data randomization is performed independently on each burst of uplink and downlink data (i.e. not on pilots and preambles) on the subchannels in the frequency domain and OFDM symbols in the time domain. If the amount of data to transmit does not fit exactly the amount of data allocated, padding of 0xFF ("1"s only) shall be added to the end of the transmission block for the unused integer number of bytes, up to the amount of data allocated. For RS-CC and CC encoded data, padding will be added to the end of the transmission block, up to the amount of data allocated minus one byte, which shall be reserved for the introduction of a 0x00 tail byte by the FEC. For CTC, if implemented, padding will be added to the end of the transmission block, up to the amount of data allocated.

The Pseudo Random Binary Sequence (PRBS) generator shall be $1 + x^{14} + x^{15}$ as shown in figure 3. Each data byte to be transmitted shall enter sequentially into the randomizer, most significant bit (MSB) first. The seed value shall be used to calculate the randomization bits, which are combined in an XOR operation with the serialized bit stream of each burst. The "data out" bits from the randomizer shall be applied to the FEC.

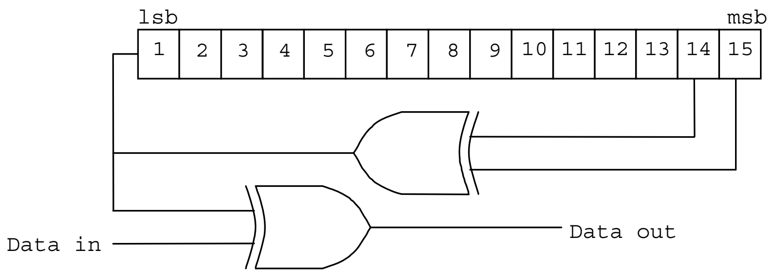

Figure 3: Data randomization PRBS

On the DL, the randomizer shall be re-initialized at the start of the FCH and at the start of the STC zone only in the case a FCH-STC is present, with the vector: 1 0 0 1 0 1 0 1 0 0 0 0 0 0 0. The randomizer shall not be reset at the start of the burst immediately following FCH or FCH-STC. At the start of subsequent bursts the randomizer shall be initialized with the vector shown in figure 4. The OFDM symbol number (i.e. the number of the first OFDM symbol of the data burst) shall be counted from the start of the DL-subframe, the first symbol being counted as symbol #0.

For a DL subchannelization zone the randomizer is initialized in an equivalent manner. At the start of the DL subchannelized zone, the randomizer shall be re-initialized to the sequence 1 0 0 1 0 1 0 1 0 0 0 0 0 0 0. The randomizer shall not be reset at the start of the first burst in the CCH. At the start of subsequent bursts, the randomizer shall be initialized with the vector shown in figure 4. The frame number used for initialization refers to the frame in which the subchannelized burst is transmitted and can be obtained from the SBCH_DLFP (refer to table 12).

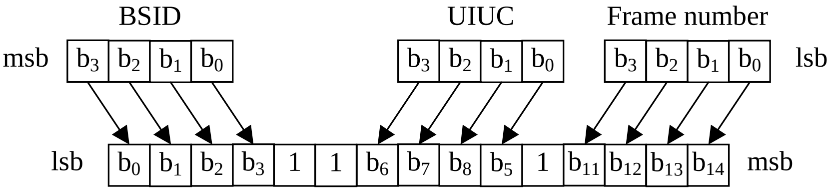

Figure 4: Scrambler DL initialization vector for bursts #2 to *N*

On the UL, the randomizer shall be initialized with the vector shown in figure 5. The frame number used for initialization is that of the frame in which the UL map that specifies the uplink burst was transmitted.

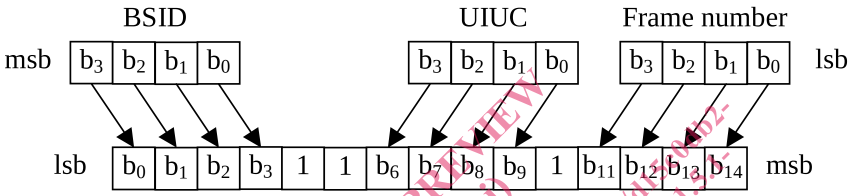

Figure 5: Scrambler UL initialization vector

4.3.2 Forward Error Correction (FEC)

The FEC consisting of the concatenation of a Reed-Solomon outer code and a rate-compatible convolutional inner code shall be supported on both UL and DL. Support of Convolutional Turbo Code (CTC) is optional. The most robust burst profile shall always be used as the coding mode when requesting access to the network and in the Frame Control Header (FCH) burst.

The encoding is performed by first passing the data in block format through the RS encoder and then passing it through a convolutional encoder. Eight tail bits are introduced at the end of each allocation, which are set to zero. This tail Byte shall be appended after randomization. In the RS encoder, the redundant bits are sent before the input bits, keeping the tail bits at the end of the allocation. When the total number of data bits in a burst is not an integer number of Bytes, zero pad bits are added after the zero tail bits. The zero pad bits are not randomized. Note that this situation can occur only in subchannelization. In this case the RS encoding is not employed.

4.3.2.1 Concatenated Reed-Solomon / Convolutional Code (RS-CC)

The RS encoding shall be derived from a systematic RS (N = 255, K = 239, T = 8) code using $GF(2^8)$, where:

N is the number of overall bytes after encoding.

K is the number of data bytes before encoding.

T is the number of data bytes which can be corrected.

For the systematic code, the code generator polynomial $g(x)$, shown in equation 2, and field generator polynomial $p(x)$, shown in equation 3, shall be used.

$$g(x) = (x+\lambda^0)(x+\lambda^1)(x+\lambda^2)\ to\ (x+\lambda^{2T-1}), \qquad \lambda = 02_{HEX} \qquad (2)$$

$$p(x) = x^8 + x^4 + x^3 + x^2 + 1 \qquad (3)$$