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Foreword

This document is the Publicly Available Specification (PAS) of the TETRAPOL land mobile radio system, which shall provide digital narrow band voice, messaging, and data services. Its main objective is to provide specifications dedicated to the more demanding PMR segment: the public safety. These specifications are also applicable to most PMR networks.

This PAS is a multipart document which consists of:

Part 1 General Network Design

Part 2 Radio Air interface

Part 3 Air Interface Protocol

Part 4 Gateway to X.400 MTA

Part 5 Dispatch Centre interface

Part 6 Line Connected Terminal interface

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1. Scope

The present Part of the Specification deals with the TETRAPOL Air Interface and contains the specifications of the Physical layer. It covers the TETRAPOL radio aspects, in particular:

- the Channel Organisation;
- the Channel Coding and Frame Building;
- the Modulation;
- the Radio transmission and reception;
- the Synchronisation;
- the Radio Link Control.

2. Normative references

This PAS incorporates by dated and undated reference, provisions from other applications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revision of any of these publications apply to this PAS only when incorporated in it by amendment or revision. For undated references the latest edition of publication referred to applies.

[1] PAS 0001-1-1: "TETRAPOL Specifications; General Network Design; Reference Model".

[2] PAS 0001-3-2: "TETRAPOL Specifications; Air Interface Protocol; Air Interface Application Messages".

[3] PAS 0001-3-3: "TETRAPOL Specifications; Air Interface Protocol; Air Interface Transport Protocol".

[4] ETS 300 113: "Radio Equipment and Systems (RES); Land mobile service; Technical characteristics and test conditions for radio equipment intended for the transmission of data (and speech) and having an antenna connector".

[5] ITU-T Recommendation O.153: "Basic parameters for the measurement of error performance at bit rates below the primary rate".

3. Definitions and abbreviations

3.1. Definitions

For the purposes of this PAS, the following definitions apply:

block: A block is comprised of several consecutive segments. Each segment is coded in a frame, and the frames are transmitted on a logical channel.

coded block: A coded block is a part of a voice frame and a data frame, corresponding to the convolutional encoding output of bits needing protection.

data segment: A data segment is a set of 64+2 data bits coming from the transport level. The 160-bit data frame results from the coding of a data segment and the 2 associated signalling bits. Most often, a segment is assumed to be a data segment.

frame: A frame is a set of 160 bits, which is transmitted during a 20 ms time interval. There are 6 different kinds of frames: data frames, voice frames, random access frames, training frames, SCH/TI frames and Direct Mode Emergency Frames.

high-rate data segment: A high-rate data segment is a set of 94+2 data bits coming from the transport level. The 160-bit high-rate data frame results from the coding of a high-rate data segment and the 2 associated signalling bits.

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logical channel: A logical channel is a subset of the superframe. Logical channels are mapped to the superframe depending on the frame numbers.

speech segment: A speech segment is a set of 120 bits coming from the CODEC. The 160-bit voice frame results from the coding of a speech segment and the 2 associated signalling bits.

superframe: A superframe is a set of 200 consecutive frames, numbered from 0 to 199. It lasts 4 seconds.

time interval: A time interval is a physical structure of 20 ms period of time, corresponding to 160 modulation symbols.

3.2. Abbreviations

For the purposes of this PAS, the following abbreviations apply:

A/I	Air Interface
AGC	Automatic Gain Control
ASB	Associated Signalling Bits
BCH	Broadcast CHannel
BER	Binary Error Rate
BN	Base Network
BS	Base Station
CCH	Control CHannel
DACH	Dynamic random Access CHannel
DCH	Data CHannel
FBM	FallBack Mode
FER	Frame Erasure Rate
FN	Flag Number
GMSK	Gaussian Minimum Shift Keying
LLC	Logical Link Control
MAC	Medium Access Control
MS	Mobile Station
OMC	Operation and Maintenance Centre
PCH	Paging CHannel
PTT	Push-To-Talk
RACH	Random Access CHannel
RCH	Random access answer CHannel
RP	RePeater
RT	Radio Terminal
SCH	Signalling CHannel
SCH/TI	Signalling CHannel/Transmitter Interruption
SCR	SCRambling parameter
SDCH	Signalling and Data CHannel
SDL	Specification and Description Language
ST	System Terminal
SwMI	Switching and Management Infrastructure
TCH	Traffic CHannel
TMSG-Id	Temporary MeSsaGe Identifier
TP	TransPort layer
TPBS	Transmitted Power of a Base Station
TPT	Transmitted Power of a Terminal
UHF	Ultra High Frequency
VCH	Voice CHannel
VHF	Very High Frequency

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4. Physical link organisation

4.1. Frequency organisation

TETRAPOL systems may operate at radio frequencies of 70 MHz to 520 MHz. Channel spacing shall consist of 12,5 or 10 kHz versions, with a possible 6,25 kHz extension. The modulation type is Gaussian Minimum Shift Keying (GMSK), with parameter BT = 0,25 as defined in Clause 7.

There are 2 versions of the air interface. The first one (Very High Frequency Version) is designed for operating at radio frequencies below 150 MHz. The second one (Ultra High Frequency Version) is designed for radio frequencies over 150 MHz. The whole part of the air interface is common, except for data and voice frames, in which the interleaving and the differential encoding are different depending of the version type.

The TETRAPOL Radio System can, unless otherwise specified, support a 5 MHz bandwidth corresponding to 500 radio channels of 10 kHz or 400 radio channels of 12.5 kHz. The frequency shift between the uplink and downlink of the same radio channel is constant (duplex spacing). The recommended value in the UHF band is 10 MHz.

The duplex spacing and channel spacing (10 or 12.5 kHz) are project dependent variables.

Generally, terminals operate in half-duplex mode.

4.2. Network Mode

Duplex channels enable radio transmissions between a Base Station (BS) and a Radio Terminal (RT) in the TETRAPOL System.

A Base Station (BS) transmits on n radio channels (n = 1 to 24), one of which supports the Control Channel (CCH). All the clocks of the BS are derived from a unique pilot, in phase on the n channels. Using the Control Channel, the RT acquires the synchronisation at physical level: pilot frequency, bit synchronisation, Time Interval synchronisation. The RT is then synchronised on the n downlink channels, and maintains this synchronisation on the uplink channels, and when changing between Traffic Channel and CCH.

Frames are organised in Superframes, with a 4 second period (or 200 frames). The Terminal extracts the Superframe synchronisation from the CCH, by the detection of PCH and BCH frames (see PAS 0001-3-3 [3]).

Transmission is organised in Frames of 160 bits, each Frame being transmitted during a 20 ms Time Interval (equivalent to 160 modulation symbols) in both directions.

The RT may then transmit during Time Intervals allocated by the BS.

There shall be 5 different kinds of Frames in Network Mode:

- Voice Frame: Downlink and Uplink direction, described in subclause 6.1;
- Data Frame: Downlink and Uplink direction, described in subclause 6.2;
- Random Access Frames: Uplink direction only, described in subclause 6.3;
- Training Frame: Uplink direction only, described in subclause 6.4;
- SCH/TI Frames: Downlink direction only, described in subclause 6.6.

The Training Frame is a deterministic frame which shall carry no varying information. The SCH/TI frames carry only 5 bits of information. The Voice Frames, Data Frames and Random Access Frames are processed as described in Figure 1. All these frames are transmitted in 20 ms Time Intervals.

All Terminal transmissions in the uplink direction start with a training Frame except Random Access frames.

The channel coding of Voice and Data frames is similar for the first coded block, which contains a discriminator bit indicating the coding of the following block.

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The Random Access Frame is only sent in the uplink direction, at precise time intervals in Superframe defined by the Network (see RACH description in subclause 5.3).

Channel coding in coded blocks is based on convolutional and CRC codes.

Interleaving is applied to Voice, Data and Random Access frames for protection against fading.

Scrambling is used to avoid repetitive patterns for security reasons and for protection against interferences.

A different Scrambling parameter value may be used for each communication and from one radio channel to another. The Scrambling parameter used on the CCH in the downlink direction is a System constant, to enable the initial synchronisation of the terminal. This downlink CCH gives the RT the scrambling parameters used on the other channels, and on the CCH in the uplink direction.

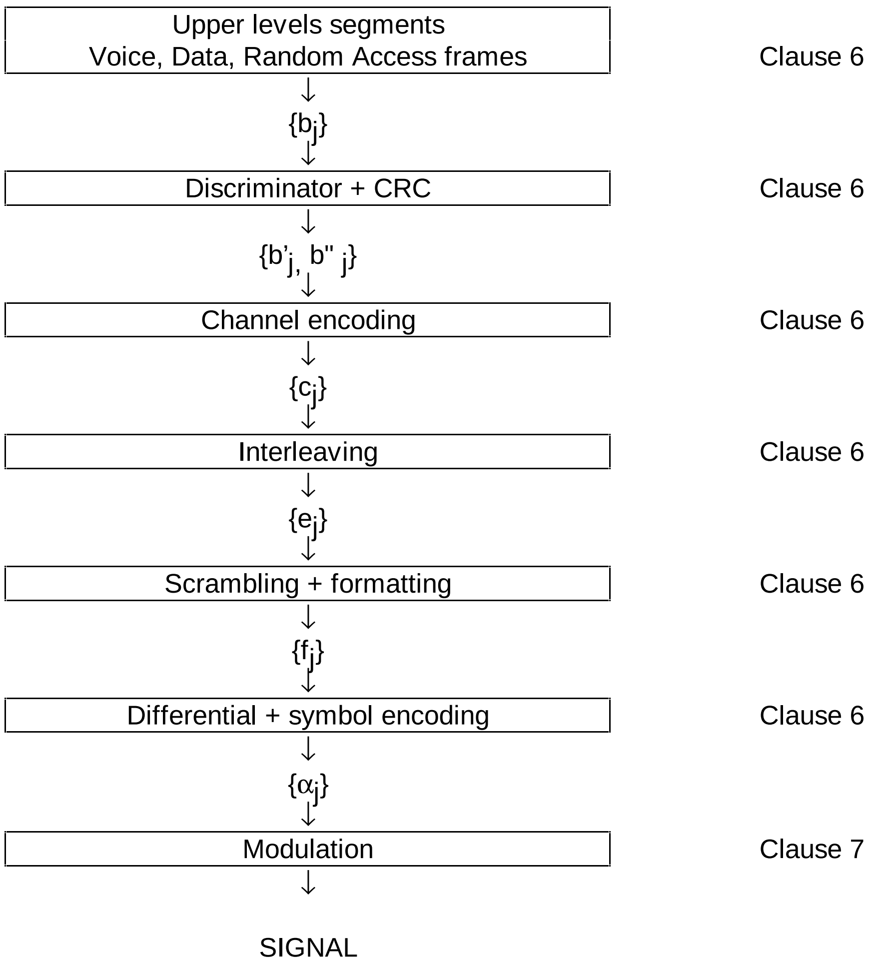

Figure 1: General frame building scheme

4.3. Repeater Mode

The Repeater Mode is a special case of the Network Mode. It is characterised by the absence of CCH and a unique TCH. The scrambling parameter of the TCH channel is a system constant, usually different for adjacent channels.

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4.4. Direct Mode

Direct Mode channels enable radio transmissions between 2 Radio Terminals (RT) in the TETRAPOL System in Half-Duplex mode. The channel spacing is the same as in Network Mode.

The RT does not need any synchronisation information to transmit on a Direct Mode Channel. The receiving RTs acquire the synchronisation at physical level: pilot frequency, bit synchronisation, Time Interval synchronisation from the transmitting RT.

There shall be 3 different kinds of Frames in Direct Mode:

- Voice Frame: described in subclause 6.1;
- Data Frame: described in subclause 6.2;
- Direct Mode Emergency Frame: described in subclause 6.5.

The Direct Mode Emergency Frame is a deterministic frame which carries no varying information. The coding of Voice and Data Frames is the same as in Network Mode. The scrambling parameter of each Direct Mode channel is a system constant, usually different for adjacent channels.

Superframes are not synchronised between RTs.

5. Channel organisation

5.1. Radio organisation

Cell radio channels are duplex, they carry 2 radio links in opposite directions supporting bi-directional transmissions.

The SwMI → ST radio link is called the downlink.

The ST → SwMI radio link is called the uplink.

There are two types of radio channels: Control Radio Channels and Traffic Radio Channels.

A radio channel carries a set of Logical Channels, some of which are bi-directional. Each logical channel uses one part of the Superframe frames.

5.2. The Superframe

Each radio link of a radio channel is a succession of 160-bit frames transmitted during 20 ms Time Intervals. The gross bit rate is therefore 8 kbit/s.

A set of 200 consecutive frames forms a Superframe lasting 4 seconds.

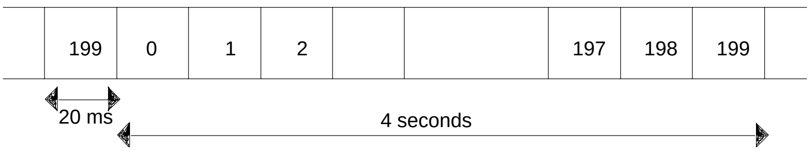

Figure 2: the Superframe

Frames are numbered from 0 to 199, the reference pattern is provided by the control channel.

Channel coding depends on the type of logical channel to which the frame belongs.

5.3. Logical Channels description

A multiplex of different logical channels is mapped on each radio channel depending on the function to be performed: Access, Signalling and Data, Broadcast, Paging, Traffic. Logical channels are mapped to the radio channels depending on the frame numbers in the Superframe.

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There are 2 types of logical channels:

- Permanent Logical Channels:
  These logical channels are built from predefined (by their number in the Superframe) radio channel frames;
- Stealing Frame Logical Channels:
  These logical channels are built by "stealing" frames normally assigned to another logical channel. Only the SwMI can perform this operation.

PAS 0001-3-3 [3] describes how blocks exchanged on these Logical Channels are mapped on several segments, each segment being coded on a frame and transmitted during a time interval. For example, the 64+2 bits DATA segment and the 2 ASB are coded on a 160 bits DATA frame.

5.3.1. Logical Channels on the Control Radio Channel

5.3.1.1. Presentation

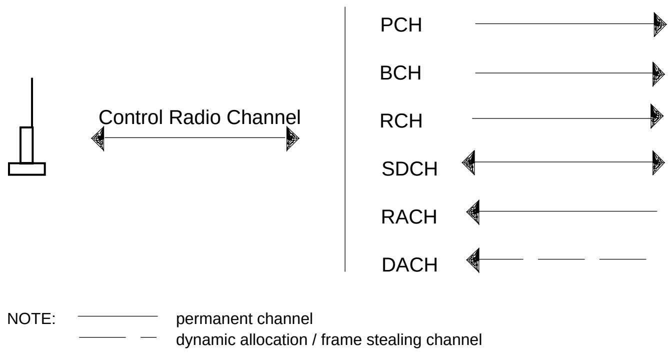

Figure 3: Control Logical Channels

There are main and extended Control Radio Channels, the latter allowing to expand the main control capacity.

The Logical Control Channels are:

- Uni-directional Downlink Logical Channels;
- Uni-directional Uplink Logical Channels.

5.3.1.2. Uni-directional Downlink Logical Channels

PCH: Paging CHannel (permanent).
Comprises frames 98, 99 and 198, 199.
Channel frame coding type is: DATA.
It is used by the SwMI to page the ST. The ST shall always monitor this channel.

BCH: Broadcast CHannel (permanent).
Comprises frames 0, 1, 2, 3, 100, 101, 102, 103.
Channel frame coding type is: DATA.
It is used by the SwMI to broadcast cell and network state information to all STs.

RCH: Random access answer CHannel (permanent).
Comprises frames 14 + i x 25, i = 0 to 7.
Channel frame coding type is: DATA.
It is used by the SwMI to acknowledge random access requests made by an ST on the Random Access Channel.

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5.3.1.3. Uni-directional Uplink Logical Channels

RACH: Random access channel (permanent).
Comprises frames (0 + i x 25) and (1 + i x 25) and (2 + i x 25) where i = 0, ..., 7.
Channel frame coding type is: RACH.
It is used by the ST to send an access request to establish or restore a dialogue with the SwMI.

DACH: Dynamic random Access CHannel (by dynamic allocation).
Comprises frames designated by the SwMI as available for this use.
Channel frame coding type is: DATA.
It is used by the ST to send a dynamic random access request to transmit a short information message.

5.3.1.4. Bi-directional Logical Channels

SDCH: Signalling and Data CHannel (permanent).
Comprises all the other frames.
Channel frame coding type is: DATA.
It is used for signalling purposes and data exchanges between the SwMI and the ST. This channel provides a point-to-point / point-to-multipoint link.

5.3.2. Logical Channels on the Traffic Radio Channel

5.3.2.1. Presentation

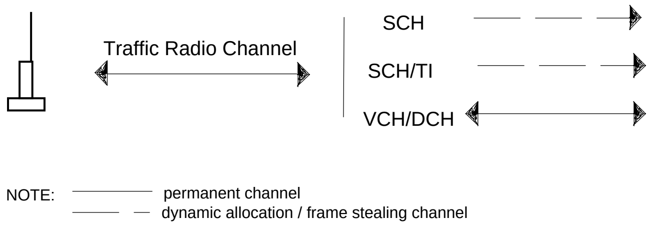

Figure 4: Traffic Logical Channels

5.3.2.2. Uni-directional Downlink Logical Channels

SCH/TI: Signalling channel for transmitter interruption (by stealing).
Comprises (when present) frame 0 of each Superframe.
Channel frame coding type is: SCH_TI.
It is used by the SwMI to force the transmitting ST to switch to receive mode. The transmitting ST shall always monitor this channel.
When the SwMI does not send SCH_TI, frame 0 contains a VCH/DCH frame.

SCH: Signalling CHannel (by stealing).
Channel built by stealing VCH/DCH frames.
Channel frame coding type is: DATA.
Used by the SwMI for signalling when the RT is present on VCH/DCH.

5.3.2.3. Bi-directional Logical Channel

VCH/DCH: Voice Channel or Data Channel (permanent).
Comprises all of the other Superframe frames.
Channel frame coding type is: DATA or HIGH RATE DATA for Data traffic and VOICE for Voice traffic.
It is used for both voice and data transmissions.

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6. Channel Coding and Frame Building

The present Clause describes the coding, interleaving, scrambling, and formatting of frames. There shall be seven types of frames: Voice Frames, Data Frames, High Rate Data Frames, Random Access Frames, Direct Mode Emergency Frames, Signalling Channel/Transmitter Interruption (SCH/TI) Frames, and Training Frames.

6.1. Voice Frames

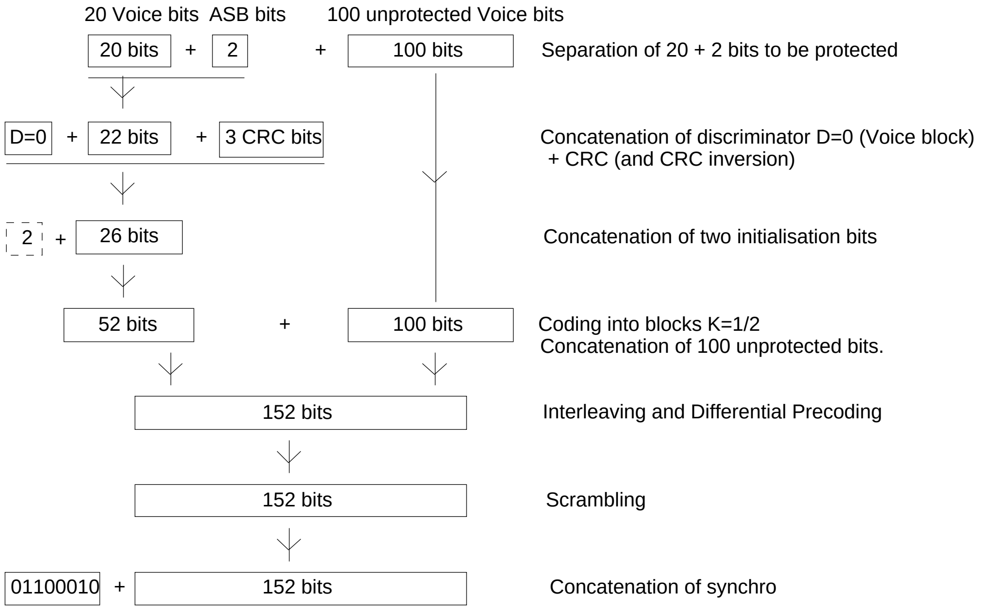

Figure 5: Voice Frame building

Voice Frames shall be constructed with 120 bits speech segments coming from the CODEC, in which the 20 first bits defined by $\{v_0 \; .... \; v_{19}\}$ shall be more protected than the 100 next numbered $v_{20}, ...v_{119}$, and 2 associated signalling bits ASB bit X and ASB bit Y defined in PAS 0001-3-3 [3].

Voice Frames are defined by b_0 .... b_{121}:

$b_i = v_i$ for i = 0 to 19

b_{20} = ASB bit X

b_{21} = ASB bit Y

$b_i = v_{i-2}$ for i = 22 to 121

Bits b_0 to b_{21} shall be protected by channel encoding.

6.1.1. Discriminator and CRC

Bits b''_j , j = -2, -1, 0,... 25 shall be defined by:

$b'_0 = 0$ (Voice/Data Discriminator)

$b'_{j+1} = b_j$, j = 0,... 21 (Voice and Associated Signalling Bits to be protected)

$b'_{23}, b'_{24}, b'_{25}$ shall be defined by:

$$(b'_0 D^{25} + b'_1 D^{24} + ... + b'_{24} D + b'_{25}) \text{ is a multiple of } (I + D + D^3)$$

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The next operation shall realise the one's complement of the CRC bits in the Voice Frame so that the frame containing 152 zeros is not a valid Voice Frame:

$b''_j = b'_j$, j = 0,...22

$b''_j = 1 - b'_j$, j = 23,24,25

The first coded block shall be cyclically encoded, and therefore two initialisation bits shall be defined:

$b''_{-2} = b''_{24}$ and $b''_{-1} = b''_{25}$

6.1.2. Channel encoding

The coded bits C_0 ... C_{151} shall be defined by:

$C_{2j} = (b''_j + b''_{j-1} + b''_{j-2})$ modulo 2, j = 0,... 25

$C_{2j+1} = (b''_j + b''_{j-2})$ modulo 2, j = 0,... 25

$C_j = b_{j-30}$, j = 52,...151 (unprotected bits)

6.1.3. Interleaving and differential precoding in VHF Version

6.1.3.1. Interleaving in VHF Version

The interleaved bits e_0,..., e_{151} shall be defined by:

$e_{k(j)} = c_j$, j = 0,...151

with $k(j) = 19\,p(j \bmod 8) + \left(3\left\lfloor \frac{j}{8} \right\rfloor \bmod 19\right)$

in which p is the bit reverse function defined by:

p(0) = 0 , p(1) = 4 , p(2) = 2 , p(3) = 6 , p(4) = 1 , p(5) = 5 , p(6) = 3 , p(7) = 7.

and $\lfloor x \rfloor$ is the integer part of x.

Example: k(123) = 19 p(3) + (3*15 mod 19) = 19*6 + 7 = 121, with 123 = 15 * 8 + 3

6.1.3.2. Differential precoding in VHF Version

There is no differential precoding in the VHF Version.

$e'_j = e_j$, j = 0 ... 151.

6.1.4. Interleaving and differential precoding in UHF Version

6.1.4.1. Interleaving in UHF Version

This part of the channel encoding is specific to the UHF Version.

The interleaved bits e_0,..., e_{151} shall be defined by:

$e_k = c_j$, j = 0,...151

with k = K(j) where K is the line vector defined by:

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K = [

1	77	38	114	20	96	59	135
3	79	41	117	23	99	62	138
5	81	44	120	26	102	65	141
8	84	47	123	29	105	68	144
11	87	50	126	32	108	71	147
14	90	53	129	35	111	74	150
17	93	56	132	37	113	73	4
0	76	40	119	19	95	58	137
151	80	42	115	24	100	60	133
12	88	48	121	30	106	66	139
18	91	51	124	28	104	67	146
10	89	52	131	34	110	70	149
13	97	57	130	36	112	75	148
6	82	39	116	16	92	55	134
2	78	43	122	22	98	61	140
9	85	45	118	27	103	63	136
15	83	46	125	25	101	64	143
7	86	49	128	31	107	69	142
21	94	54	127	33	109	72	145

]

Example: K(0)=1 , K(1) = 77, K(2) = 38, K(150)=72, K(151) = 145.

6.1.4.2. Differential precoding in the UHF Version

Differential precoding shall be performed at this point in the UHF Version.

Let PRE_COD be the line vector with 47 values defined by:

PRE_COD = [

7	10	13	16	19	22	25	28	31	34	37	40
43	46	49	52	55	58	61	64	67	70	73	76
83	86	89	92	95	98	101	104	107	110	113	116
119	122	125	128	131	134	137	140	143	146	149	]

The differential encoding shall be performed as follows:

$e'_0 = (e_0 + f_7)$ modulo 2 , where f_7 is defined in subclause 6.1.5.2.

For j = 1 to 151

If j is an element of PRE_COD,

$e'_j = (e_j + e'_{j-2})$ modulo 2,

Else

$e'_j = (e_j + e'_{j-1})$ modulo 2.

Example: $e'_1 = (e_1 + e'_0)$ modulo 2 and $e'_7 = (e_7 + e'_5)$ modulo 2.

6.1.5. Scrambling and formatting

Scrambling shall be performed on each frame. It shall be defined by a fixed sequence (see below) and a Scrambling parameter (SCR) where SCR $\in$ [0,127]. This parameter is the U_CH_SCRAMBLING parameter for uplink and D_CH_SCRAMBLING for downlink as described in PAS 0001-3-2 [2].

6.1.5.1. Scrambling Sequence

The s(k) sequence, $k \geq 0$ (with a period of 127) shall be defined by:

$s(k) = 1$, $k = 0, 1, 2, 3, 4, 5, 6$

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s(k) = (s(k-1) + s(k-7)) modulo 2 for k > 6

The S(SCR,k) sequence described by the SCR parameter shall be:

S(SCR,k) = s(k+SCR)   for all $k \geq 0$ and $SCR \neq 0$,

S(0,k) = 0   for all $k \geq 0$.

6.1.5.2. Format Definition

The formatted bits f_0 to f_{159} shall be defined by:

$\{f_0 \ldots f_7\} = \{0\ 1\ 1\ 0\ 0\ 0\ 1\ 0\}$

and $f_{8+k} = (e'_k + S(SCR,k))$ modulo 2 , for k = 0,..., 151

6.2. Data Frames

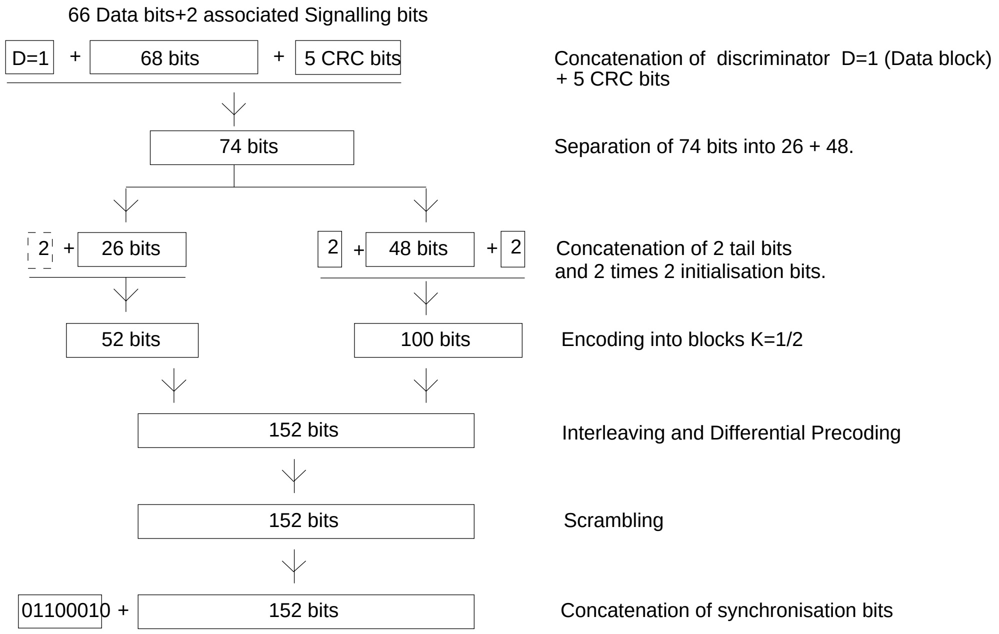

Figure 6: Data frame building

Data Frames shall be defined by 64 encrypted bits (b_2, ... , b_{65}), 2 FN Flag Number Bits ($b_0 = FN_0$, $b_1 = FN_1$) and 2 ASB Associated Signalling Bits (b_{66} = ASB bit X, b_{67} = ASB bit Y).
The use of ASB and FN bits is specified in PAS 0001-3-3 [3].

6.2.1. Discriminator and CRC

Bits d_j , j = 0, 1,... 73 shall be defined by:

$d_0 = 1$ (Voice/Data discriminator)

$d_{j+1} = b_j$, j = 0,...67

d_{69},..., d_{73} are defined by:

$$(d_0 D^{73} + d_1 D^{72} + \ldots + d_{72} D + d_{73}) \text{ is a multiple of } (I+D^2+D^5)$$

Bits b'_j, j = -2,-1,0,1,...25 shall then be defined by:

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$b'_j = d_j$, j = 0,... 25

$b'_{-2} = d_{24}$ and $b'_{-1} = d_{25}$

and bits b''_j, j = -2,-1,0,1,... 49 by:

$b''_j = d_{j+26}$, j = 0,...47

$b''_{-2} = b''_{-1} = b''_{48} = b''_{49} = 0$

6.2.2. Channel encoding

The coded bits C_0,... ,C_{151} shall be defined by:

$C_{2j} = (b'_j + b'_{j-1} + b'_{j-2})$ modulo 2 , j = 0,...25

$C_{2j+1} = (b'_j + b'_{j-2})$ modulo 2 , j = 0,...25

and

$C_{2j+52} = (b''_j + b''_{j-1} + b''_{j-2})$ modulo 2 , j = 0,...49

$C_{2j+53} = (b''_j + b''_{j-2})$ modulo 2 , j = 0,...49

6.2.3. Interleaving and differential precoding in VHF Version

6.2.3.1. Interleaving in VHF Version

The interleaved bits e_0,..., e_{151} shall be defined by:

$e_{k(j)} = c_j$, j = 0,...151

with $k(j) = 19\,p(j \bmod 8) + \left(3\left\lfloor \frac{j}{8} \right\rfloor \bmod 19\right)$

in which p is the bit reverse function defined by:

p(0) = 0 , p(1) = 4 , p(2) = 2 , p(3) = 6 , p(4) = 1 , p(5) = 5 , p(6) = 3 , p(7) = 7.

and $\lfloor x \rfloor$ is the integer part of x.

Example: k(123) = 19 p(3) + (3*15 mod 19) = 19*6 + 7 = 121, with 123 = 15 * 8 + 3

6.2.3.2. Differential precoding in VHF Version

There is no differential precoding in the VHF Version.

$e'_j = e_j$, j = 0 ... 151.

6.2.4. Interleaving and differential precoding in UHF Version

6.2.4.1. Interleaving in UHF Version

This part of the channel precoding is specific to the UHF Version.

The interleaved bits e_0,..., e_{151} shall be defined by:

$e_k = c_j$, j = 0,...151

with k = K(j) where K is the line vector defined by:

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K = [

1	77	38	114	20	96	59	135
3	79	41	117	23	99	62	138
5	81	44	120	26	102	65	141
8	84	47	123	29	105	68	144
11	87	50	126	32	108	71	147
14	90	53	129	35	111	74	150
17	93	56	132	37	112	76	148
2	88	40	115	19	97	58	133
4	75	43	118	22	100	61	136
7	85	46	121	25	103	64	139
10	82	49	124	28	106	67	142
13	91	52	127	31	109	73	145
16	94	55	130	34	113	70	151
0	80	39	116	21	95	57	134
6	78	42	119	24	98	60	137
9	83	45	122	27	101	63	140
12	86	48	125	30	104	66	143
15	89	51	128	33	107	69	146
18	92	54	131	36	110	72	149

]

Example: K(0)=1 , K(1) = 77, K(2) = 38, K(150)=72, K(151) = 149.

6.2.4.2. Differential Precoding in UHF Version

Differential precoding shall be performed at this point in the UHF Version.

Let PRE_COD be the line vector with 47 values defined by:

PRE_COD = [

7	10	13	16	19	22	25	28	31	34	37	40
43	46	49	52	55	58	61	64	67	70	73	76
83	86	89	92	95	98	101	104	107	110	113	116
119	122	125	128	131	134	137	140	143	146	149	]

The differential encoding shall be performed as follows:

$e'_0 = (e_0 + f_7)$ modulo 2, where f_7 is defined in subclause 6.2.5.2.

For j = 1 to 151

If j is an element of PRE_COD,

$e'_j = (e_j + e'_{j-2})$ modulo 2,

Else

$e'_j = (e_j + e'_{j-1})$ modulo 2.

Example: $e'_1 = (e_1 + e'_0)$ modulo 2 and $e'_7 = (e_7 + e'_5)$ modulo 2.

6.2.5. Scrambling and Formatting

Scrambling shall be performed on each frame. It shall be defined by a fixed sequence (see below) and a Scrambling parameter (SCR) where SCR $\in$ [0,127]. This parameter is the U_CH_SCRAMBLING parameter for uplink and D_CH_SCRAMBLING for downlink as described in PAS 0001-3-2 [2].

6.2.5.1. Scrambling Sequence

The s(k) sequence, $k \geq 0$ (with a period of 127) shall be defined by:

s(k) = 1, k = 0, 1, 2, 3, 4, 5, 6

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s(k) = (s(k-1) + s(k-7)) modulo 2 for k > 6

The S(SCR,k) sequence described by the SCR parameter shall be:

S(SCR,k) = s(k+SCR) for all k ≥ 0 and SCR ≠ 0,

S(0,k) = 0 for all k ≥ 0.

6.2.5.2. Format definition

Formatted bits f_0 to f_{159} shall be defined by:

$\{f_0 \ldots f_7\} = \{0\ 1\ 1\ 0\ 0\ 0\ 1\ 0\}$

and $f_{8+k} = e'_k + s(SCR,k)$ modulo 2, for k = 0,..., 151

6.3. High Rate Data Frames

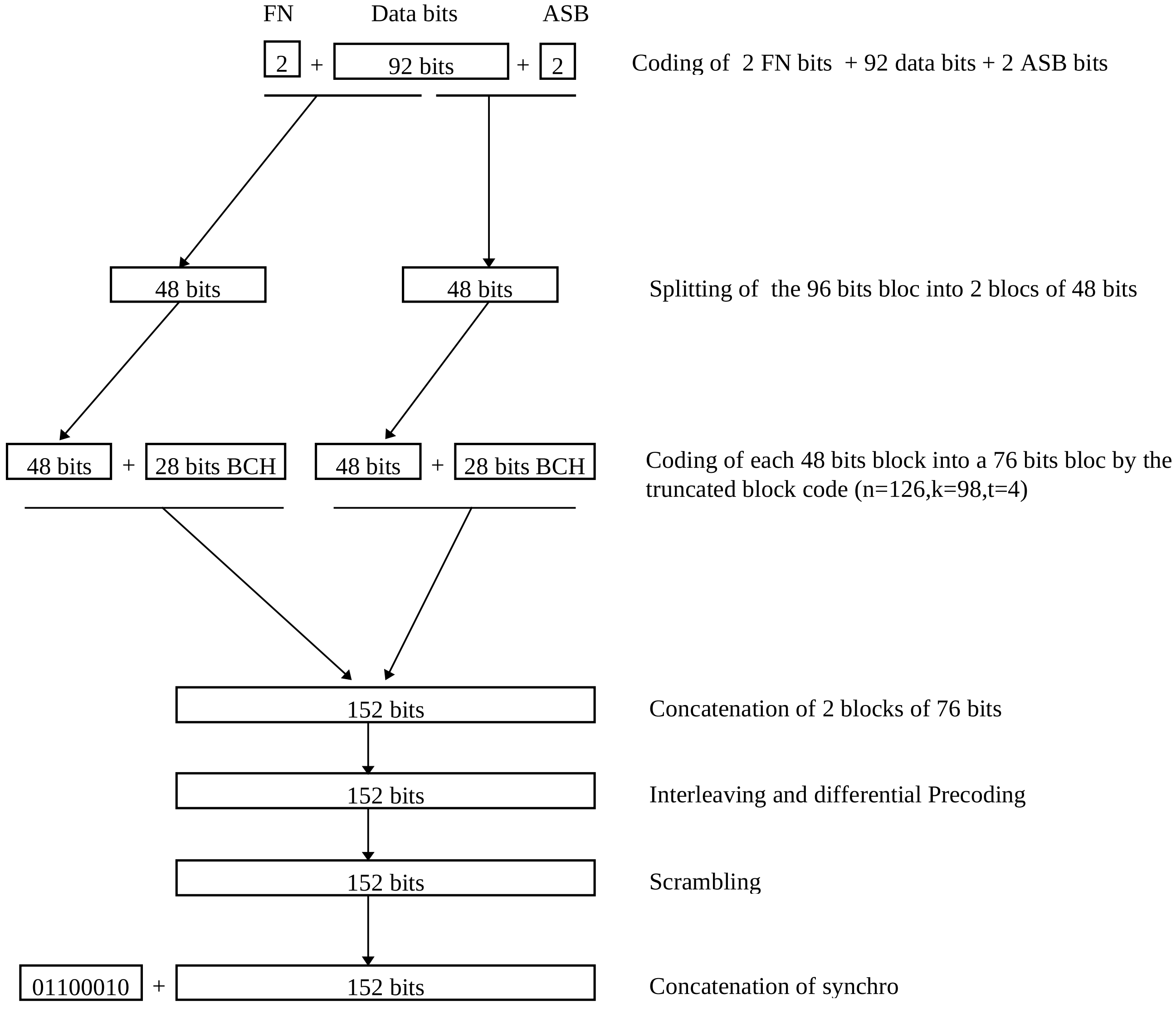

Figure x: High Rate Data Frame building

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High Rate Data Frames shall be defined by 2 FN Flag Number Bits (b_0=FN_0, b_1=FN_1), 92 encrypted bits (b_2, ... , b_{93}), and 2 ASB Associated Signalling Bits (b_{94}=ASB bit X, b_{95}=ASB bit Y).

The use of ASB and FN bits is specified in PAS 0001-3-3 [3].

6.3.1. Discriminator and CRC

There is no discriminator in High Rate Data Frames.

The CRC is a virtual measure given by the first level of channel coding

6.3.2. Channel encoding

The first block coded bits a_0 ... a_{75} shall be defined by:

a_0 ,...,a_{47} are defined by : $a_j = b_j$, j = 0 ...47

a_{48},..., a_{75} are defined by:

$(a_0D^{75} + a_1 D^{74} + ... + a_{74} D + a_{75})$ is a multiple of

$(I+D^3+D^4+D^5+D^7+D^9+D^{10}+D^{13}+D^{18}+D^{19}+D^{20}+D^{23}+D^{26}+D^{27}+D^{28})$.

The second block coded bits a_{76} ... a_{151} shall be defined by:

a_{76} ,...,a_{123} are defined by : $a_{j+28} = b_j$, j = 48 ...95

a_{124},..., a_{151} are defined by:

$(a_{76}D^{75} + a_{77} D^{74} + ... + a_{150} D + a_{151})$ is a multiple of

$(I+D^3+D^4+D^5+D^7+D^9+D^{10}+D^{13}+D^{18}+D^{19}+D^{20}+D^{23}+D^{26}+D^{27}+D^{28})$.

Note : $I+D^3+D^4+D^5+D^7+D^9+D^{10}+D^{13}+D^{18}+D^{19}+D^{20}+D^{23}+D^{26}+D^{27}+D^{28}=$

$(I+D^3+D^7)\ (I+D+D^2+ D^3+D^7)(I+D^2+D^3+D^4+D^7)\ (I+D+D^2+D^4+ D^5+ D^6+D^7)$

6.3.2.1. Interleaving

The interleaving is common to VHF and UHF versions.

The interleaved bits e_0,..., e_{151} shall be defined by:

$e_{k(j)} = a_j$, j = 0,...151

with k(n) = 2n and k(76 + n) = 2n+1 with n = 0 ... 75

Example: k(0) = 0, k(76) = 1, k(1) = 2, ...

6.3.3. Differential precoding in VHF and UHF Version

6.3.3.1. Differential precoding in VHF Version

There is no differential precoding in the VHF Version.

$e'_j = e_j$, j = 0 ... 151.

6.3.3.2. Differential precoding in the UHF Version

Differential precoding shall be performed at this point in the UHF Version.

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The differential encoding shall be performed as follows:

$e'_0 = (e_0 + f_7)$ modulo 2 , where f_7 is defined in subclause 6.1.5.2.

For j = 1 to 151, $e'_j = (e_j + e'_{j-1})$ modulo 2,

6.3.4. Scrambling and formatting

Scrambling shall be performed on each frame. It shall be defined by a fixed sequence (see below) and a Scrambling parameter (SCR) where SCR $\in$ [0,127]. This parameter is the U_CH_SCRAMBLING parameter for uplink and D_CH_SCRAMBLING for downlink as described in PAS 0001-3-2 [2].

6.3.4.1. Scrambling Sequence

The s(k) sequence, $k \geq 0$ (with a period of 127) shall be defined by:

s(k) = 1, k = 0, 1, 2, 3, 4, 5, 6

s(k) = (s(k-1) + s(k-7)) modulo 2 for k > 6

The S(SCR,k) sequence described by the SCR parameter shall be:

S(SCR,k) = s(k+SCR) for all $k \geq 0$ and SCR $\neq$ 0,

S(0,k) = 0 for all $k \geq 0$.

6.3.4.2. Format Definition

The formatted bits f_0 to f_{159} shall be defined by:

$\{f_0 \ldots f_7\} = \{0\ 1\ 1\ 0\ 0\ 0\ 1\ 0\}$

and $f_{8+k} = (e'_k + S(SCR,k))$ modulo 2 , for k = 0,..., 151

6.4. Random Access Frames

These frames shall be used at the start of applicative RT uplink transmissions.

The 20 ms time interval shall comprise:

- 3 ms (24 bits): transmitter power rise;
- 3,625 ms (29 bits): signal for adjusting the AGC on the base station receiver;
- 12,750 ms (102 bits): main sequence, comprised of 3 synchronisation sequences separated by 2 information sequences;
- 0,625 ms (5 bits): guard word to provide for a possible frame delay.

RACH frames shall be defined by 14 bits: $b_0 \ldots b_{13}$.

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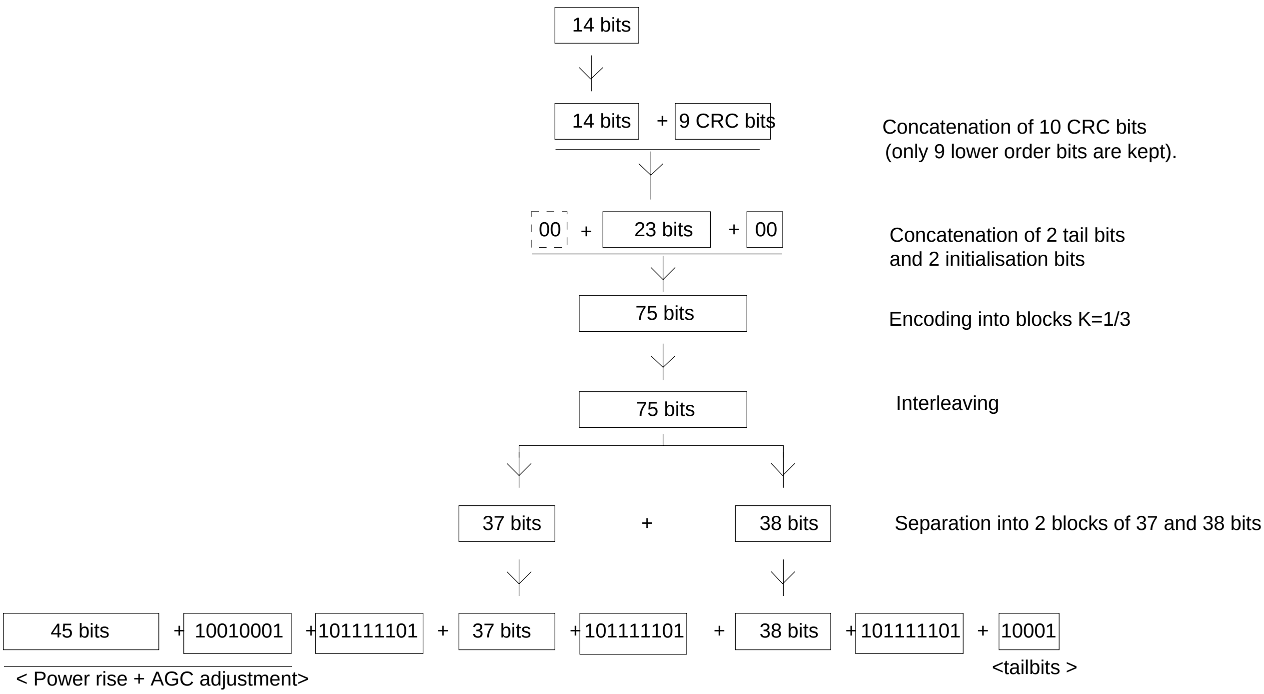

Figure 7: RACH frame building

6.4.1. CRC

Bits b''_j , j = -2,...24 shall be defined by:

$b'_j = b_j$, j = 0,...13, and,

b'_j , j = 14,... 23 are defined by:

$$(b'_0 D^{23} + b'_1 D^{22} + b'_2 D^{21} + ... + b'_{22} D + b'_{23})$$

$$\text{is a multiple of } I + D^3 + D^5 + D^6 + D^8 + D^9 + D^{10}$$

b'_{14} shall be deleted and convolutional code tail bits and initialisation bits shall be added. The one's complement of the CRC bits in the RACH frame shall be realised so that the frame containing 75 zeros is not a valid RACH Frame.

$b''_j = b'_j$, j = 0,...13

$b''_j = 1-b'_{j+1}$, j = 14,...22

$b''_{-2} = b''_{-1} = b''_{23} = b''_{24} = 0$

6.4.2. Channel Encoding

The coded bits $C_0 ... C_{74}$ shall be defined by:

$C_{3j} = (b''_j + b''_{j-2})$ modulo 2, j = 0 ...24

$C_{3j+1} = (b''_j + b''_{j-1} + b''_{j-2})$ modulo 2, j = 0 ... 24

$C_{3j+2} = (b''_j + b''_{j-1} + b''_{j-2})$ modulo 2, j = 0 ... 24

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6.4.3. Interleaving

The interleaved bits $e_0 \ldots e_{74}$ shall be defined by:

$e_k = C_j$, k = 0,...74

with j = (k x 31) modulo 75.

6.4.4. Formatting

The synchronisation sequence shall contain the following sequence:

$\{s_0 \ldots s_7\}$ = {10111110}

The power rise and AGC adjustment sequence shall contain a repeated synchronisation sequence and a sequence of 8 bits:

$f_j = s_{(j + 3) \text{ modulo } 8}$, j = 0,...44

$\{f_{45} \ldots f_{52}\}$ = {10010001}

The main sequence shall contain 3 synchronisation sequences of 7 bits + 2 guard bits, separated by 2 information sequences, of 37 and 38 bits respectively.

$f_{j+53} = s_{j \text{ modulo } 8}$, j = 0,...8

$f_{j+62} = e_j$, j = 0,...36

$f_{j+99} = s_{j \text{ modulo } 8}$, j = 0,...8

$f_{j+108} = e_j + 37$, j = 0,...37

$f_{j+146} = s_{j \text{ modulo } 8}$, j = 0,...8

A guard sequence shall be added:

$\{f_{155} \ldots f_{159}\}$ = {10001}.

6.5. Training Frame

These frames shall be used at the start of RT uplink transmissions.

The Training Frame shall be a 15 bit synchronisation sequence repeated as necessary.

$\{s_0 \ldots s_{14}\}$ = {011010111100010}

$f_j = s_{(j+5) \text{ modulo } 15}$, j = 0,...159

The 20 ms time interval shall comprise:

- 3 ms (24 bits): transmitter power rise;
- 3,875 ms (31 bits): signal for adjusting the AGC or the base station receiver;
- 11,25 ms (90 bits): main sequence comprised of 6 synchronisation sequences;
- 1,875 ms (15 bits): guard word to provide for a possible frame delay.

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6.6. Direct Mode Emergency Frame

The Direct Mode Emergency Frame shall be used as an alarm signal in Direct Mode.

The Direct Mode Emergency Frame shall contain a 32-bit pattern (repeated as necessary).

$\{f_0 \ldots f_{31}\}$ = {0101 1010 0000 1111 0101 1010 0000 1111}

$f_j = f_{j \text{ modulo } 32}$, j = 32,...159

6.7. SCH/TI Frames

The Base Station shall use these frames to interrupt terminal transmissions. These frames shall be placed at the beginning of the Superframe as requested by the Radioswitch and detected by terminals in transmit mode.

The 20 ms time interval shall comprise:

- 2 ms: end of terminal transmission;
- 5,375 ms: synthesiser switching and AGC adjustments;
- 8 ms: observation window;
- 4,625 ms: synthesiser switching and power adjustments.

6.7.1. Offset information

The TTI of the Terminal which is to be interrupted shall be identified by the Radioswitch.

The 16 bits of the TTI are coded as shown on Figure 8 (see PAS 0001-3-2 [2]).

Bits →	8	7	6	5	4	3	2	1	Octet n°
	t15	t14	t13	t12	t11	t10	t9	t8	1
	t7	t6	t5	t4	t3	t2	t1	t0	2

Figure 8: TTI coding for obtaining offset information

The offset ID (32 possible values) shall be derived as follows:

If $\{t_{15}, \ldots t_0\}$ = {X, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1}, where X = 0 or 1

ID = 31

Else

ID = $\{t_{14}, \ldots, t_1\}$ modulo 31 .

6.7.2. Detection bits

The Detection sequence shall be a cyclic sequence of 64 bits, offset by twice the value of ID. The sequence shall be written in binary, ascending left to right index,

D(0) = { 0110 0000 1111 1100 0011 1110 1001 1111

0110 1101 0010 1001 0000 0110 0111 0000 }

Let D(ID) be this periodic sequence offset of 2*ID bits, in which the k^{th} bit shall be defined by:

D(ID) (k) = D(0) [(k - 2 ID) modulo 64] for k = 0, ..., 63.

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6.7.3. Integrated sequence

Since the whole frame is precoded in the modulator, and the SCH/TI frame is detected on the modulated signal, the binary sequence shall be integrated to compensate for the differential encoding.

P_k shall be the bit string before integration and Q_k shall be the bit string after integration.

$P_k = D(ID)(k - 47)$, k = 0,...151

and:

$Q_{-1} = 0$

$Q_k = (Q_{k-1} + P_k)$ modulo 2

6.7.4. Frame to Send

The Frame to Send shall contain the frame synchronisation code followed by the integrated sequence:

$\{f_0 \ldots f_7\} = \{0, 1, 1, 0, 0, 0, 1, 0\}$, and,

$f_k = Q_{k-8}$, k=8,...159.

7. Modulation

This Clause describes the signals sent onto the antenna access. For each frame, the modulator receives formatted bits $\{f_0 \ldots f_{159}\}$. The theoretical wave form is described.

7.1. Modulation Rate

The modulation rate shall be 8 kbit/s. Therefore, the period T mentioned below is 125 µs. The symbol clock and RF signals shall be derived from the same frequency source.

7.2. Modulator

The modulator shall receive 160 bits $\{f_0, \ldots f_{159}\}$ every 20 ms.

It therefore receives a continuous bit stream:

$\{m_k\}$ containing packets of $\{f_0, \ldots, f_{159}\}$ placed end-to-end:

$\{m_k\} = \{\ldots f_{159}^{(n-1)}, f_0^{(n)}, \ldots, f_{159}^{(n)}, f_0^{(n+1)}, \ldots, f_{159}^{(n+1)}, f_0^{(n+2)}, \ldots\}$

The bits shall be differentially coded:

$M_k = (m_k + m_{k-1})$ modulo 2.

7.3. Spectral inversion

Mobile Station to Base Station transmissions shall not be spectrally inverted, the M_k bits being naturally changed to α_k symbols:

$\alpha_k = 1-2\,M_k$, $\alpha_k \in \{+1,-1\}$

However, Base Station to Mobile Station and Mobile Station to Mobile Station transmissions shall be spectrally inverted. The operation shall be performed by:

$\alpha_k = -(1-2\,M_k)$, $\alpha_k \in \{+1,-1\}$

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7.4. Modulated signal

The modulated signal shall be defined by its phase ϕ (t), with:

$$\phi(t) = \sum_i (\alpha_i \frac{\pi}{2} \int_{-\infty}^{t-iT} g(\tau) d\tau)$$

where

$g(t) = h(t) * rect(t/T)$ where the $*$ symbol stands for convolution

with

$$rect(t/T) = \begin{cases} 1/T, & \text{if } |t| \le \mathrm{T}/2 \\ 0, & \text{if } |t| > \mathrm{T}/2 \end{cases}$$

and

$$h(t) = \frac{1}{\sqrt{2\pi}\sigma T} \exp(-t^2 / (2\sigma^2 T^2))$$

with $\sigma = \frac{\sqrt{\ln(2)}}{2\pi BT}$ and $BT = 0,25$.

The transmit time t_k of the k^{th} bit m_k and its associated symbol α_k is defined as the instant t_k=kT.

7.5. RF signal

During transmission, the RF signal shall therefore be represented by:

$$x(t) = \sqrt{\frac{2E_b}{T}} \cos(2\pi f_0 t + \phi(t) + \phi_0)$$

where E_b represents the energy per modulated bit, f_0 the central frequency in the radio channel used, ϕ_0 the initial phase.

8. Radio transmission and reception

8.1. Introduction

The present Clause defines the requirements for the Mobile Station and the Base Station transceiver of the TETRAPOL system.

The TETRAPOL RF carrier separation *p* shall be 10 kHz or 12.5 kHz. Unless otherwise stated, the radio characteristics given in the following subclauses shall apply to both carrier separations. As a general rule, performances comply to ETS 300 113 [4].

8.2. Reference test planes

For testing purposes, all TETRAPOL stations shall have at least one antenna connector. Measurements shall be carried out at the appropriate antenna connector of the equipment as specified by the manufacturer. Base Stations measurements shall be performed at the receive antenna connector and at the transmit antenna connector respectively.

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8.3. Transmitter characteristics

8.3.1. Output power

In the following, power is defined as the average power, measured in 10 kHz over the transmitted bits.

The power at which Mobile Stations or Base Stations may operate is specified in the following subclauses.

8.3.1.1. Base Station

The BS transmitter nominal power shall be, according to its class, as defined in table 1:

Table 1: Nominal power of BS transmitters

Power class	Power per carrier
1 (25 W)	44 dBm
2 (16 W)	42 dBm
3 (6 W)	38 dBm
4 (2,5 W)	34 dBm
5 (1 W)	30 dBm

The BS TX nominal power shall be declared by the manufacturer within a range of +2dB –2dB centered around the power class as defined in table 1.

8.3.1.2. Mobile Station

The MS nominal power shall be, according to its class, as defined in table 2:

Table 2: Nominal power of MS transmitters

Power class	Nominal power
1 (10 W)	40 dBm
2 (2 W)	33 dBm
3 (1 W)	30 dBm

The power levels needed for adaptive power control shall have values starting from the minimum power control level up to the nominal power level corresponding to the class of the particular MS as stated in table 2. The Mobile Station (MS) output power shall be able to be reduced continuously, down to a minimum level of 19 dBm (power class 1) and 21 dBm (power class 2 and 3).

8.3.2. Unwanted conducted emissions

8.3.2.1. Definitions

Unwanted emissions are defined as conducted emissions at frequencies outside of the allocated channel. The specified limits shall be met under realistic conditions, for instance under varying antenna mismatch. A transmitter has two modes, transmit operating mode and transmit standby mode. Unless otherwise stated, unwanted emissions are specified for an equipment in transmit operating mode, i.e. whenever this equipment is transmitting, or whenever it ramps-up or ramps-down.

8.3.2.2. Unwanted emissions close to the carrier

Measurements shall be done at the nominal centre frequency and at the frequencies corresponding to the frequency offsets specified below. When applicable, relative measurements (dBc) shall refer to the level measured at the nominal centre frequency.

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8.3.2.2.1. Measurement over the useful part of the frame

The power levels given in table 3 shall not be exceeded at frequencies corresponding to the listed frequency offsets from the actual carrier frequency.

Table 3: Maximum adjacent power levels

Frequency offset	Maximum level	
	p=10 kHz	**p=12.5 kHz**
p	- 36 dBc (see note 1)	- 60 dBc (see note 2)
2×p	- 60 dBc	- 70 dBc

In any case, no requirement more stringent than - 36 dBm shall apply.

The measured values shall be averaged over the useful transmit bits. The useful transmit bits shall have a pseudo-random distribution from frame to frame.

8.3.2.2.2. Measurement during the switching transients

At 10 kHz and 12.5 kHz frequency offset from the nominal carrier frequency peak, power measurements shall be done, covering at least the ramp-up period (between T1 and T4 in Figure 9) and the ramp-down period (between Txoff and T6 in Figure 9). The maximum hold level shall not exceed the maximum adjacent power levels which are given in Table 3 at frequency offsets of 10 kHz and of 12.5 kHz respectively, with a release of 10 dBc.

In any case no requirement more stringent than - 27 dBm 12.5 kHzshall apply.

8.3.2.3. Unwanted emissions far from the carrier

These unwanted emissions are emissions (discrete, wideband noise, modulated or unmodulated) not covered by subclause 8.3.2.2 and measured in the frequency range 9 kHz to 4 GHz.

Discrete Spurious:

The maximum allowed power for each spurious emission shall be less than - 36 dBm below 1 GHz and -30 dBm between 1 GHz and 4 GHz. The lower part of the spectrum (near 9 kHz) is subject to specific measurement methods.

Wideband Noise:

The following wideband noise levels should not exceed the limits shown in the following table at frequencies corresponding to the listed offsets from the nominal carrier frequency. The requirements apply symmetrically to both sides of the transmitter band. The wideband noise shall be measured in a 8 kHz ± 0,5 kHz bandwidth filter.

Table 4: Wideband noise limits

Frequency offset	Maximum level	
	mobile station	**base station**
25 kHz - 40 kHz	**- 70 dBc**	**-70 dBc**
40 kHz - 100 kHz	- 75 dBc	- 75 dBc
100 kHz - 150 kHz	- 85 dBc	- 85 dBc
150 kHz - 500 kHz	- 90 dBc	- 95 dBc
500 kHz - 10 MHz	- 100 dBc	- 105 dBc
> 10 MHz and in the receive band	- 80 dBm	- 100 dBm

8.3.2.4. Unwanted emissions in the transmit standby mode

Specifications given in subclause 8.4.4.2 shall apply.

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8.3.3. Unwanted radiated emissions

In the case of radiated emissions specifications given in ETS 300 113 [4] shall apply.

8.3.4. Radio frequency tolerance

The BS carrier frequency shall be accurate to within ± 0,2 ppm.

In trunked mode the MS carrier frequency shall be accurate to within ± 0,2 ppm compared to the signals received from the BS.

In direct mode the MS carrier frequency shall be accurate to within ± 1,3 kHz .

8.3.5. RF Output power time mask

The transmit power level versus time shall remain within the limits given by the following time mask:

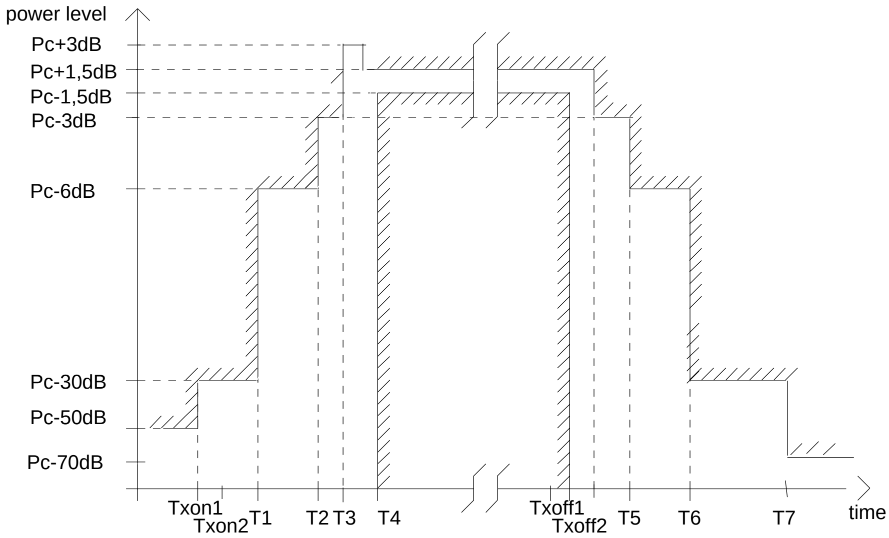

Figure 9: Time Mask

The following power, and time instants are defined by:

Pc: steady state power;

Txon1: time at which the final irrevocable logic decision to power on the transmitter is taken : time at which the first modulated symbol of a frame is transmitted.

Txon2: time after which the carrier power exceeds (Pc - 50 dB).

NOTE: Txon corresponds to Txon1, unless no access point is available, then Txon2 shall be taken instead.

The power starts to rise somewhere between Txon and T1 (RF power on);

T1: time when the carrier power, measured at the transmitter output, exceeds Pc - 30 dB;

T2: time when the carrier power, measured at the transmitter output, reaches Pc - 6 dB;

T3:

time at which the transmitter output power has reached a level 3 dB below or above the

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steady state power (Pc) and maintains a level within ± 3 dB from Pc thereafter;

T4: time at which the transmitter output power has reached a level 1,5 dB below or above the steady state power (Pc) and maintains a level within ± 1,5 dB from Pc thereafter;

Txoff1: time at which the final irrevocable logic decision to power off the transmitter is taken.

Txoff2: time after which the carrier power remains below (Pc - 3 dB).

NOTE: Txoff corresponds to Txoff1, unless no access point is available, then Txoff2 shall be taken instead.

The power starts to decrease somewhere between Txoff and T5;

T5: time when the carrier power, measured at the transmitter output, falls below Pc - 6 dB;

T6: time when the carrier power, measured at the transmitter output, falls below Pc - 30 dB;

T7: time when the carrier power, measured at the transmitter output, falls below Pc - 70 dB

8.3.5.1. MS output power time limits

The following MS limits shall hold for the time intervals listed:

Table 5: MS Time Mask limits

time interval between instants defined above	specified limit
T3 - Txon	1 ms < T3 - Txon < 3 ms
T2 - T1	T2 - T1 > 0,20 ms
T4 - T3	0 ms < T4 - T3 < 2 ms
T6 - T5	T6 - T5 > 0,20 ms
T7 - Txoff	T7 - Txoff < 2.5 ms

8.3.5.2. BS output power time limits

The following BS limits shall hold for the time intervals listed:

Table 6: BS Time Mask limits

time interval between instants defined above	specified limit
T3 - Txon	1 ms < T3 - Txon < 12 ms
T2 - T1	T2 - T1 > 0,20 ms
T4 - T3	0 ms < T4 - T3 < 6 ms
T6 - T5	T6 - T5 > 0,20 ms
T7 - Txoff	T7 - Txoff < 9 ms

8.3.6. Intermodulation attenuation

8.3.6.1. Definition

The intermodulation attenuation is the ratio of the power level of the wanted signal to the power level of an intermodulation component. It is a measure of the capability of the transmitter to inhibit the generation of signals in its non-linear elements caused by the presence of the useful carrier and an interfering signal reaching the transmitter via its antenna.

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8.3.6.2. Base station

The specifications given in ETS 300 113 [4] shall apply.

8.3.6.3. Mobile station

For an MS transmitter operating at the nominal power defined by its class, the intermodulation attenuation shall be at least 40 dB (power class 1) and 45 dB (power class 2 and 3) for any intermodulation component. The interfering signal shall be unmodulated and have a frequency offset of at least 50 kHz from the useful carrier frequency. The power level of the interfering signal shall be 30 dB (power class 1) and 40 dB (power class 2 and 3) below the power level of the modulated output signal from the transmitter under test.

8.4. Receiver characteristics

In the present subclause, the levels of the test signals are given in terms of power levels (dBm) at the antenna connector of the receiver.

Sources of test signals shall be connected in such a way that the impedance presented to the receiver input is a 50 Ω non-reactive impedance.

This requirement shall be met irrespective of whether one or more signals using a combining device are applied to the receiver simultaneously.

Static propagation conditions are assumed in all cases, for both wanted and unwanted signals.

8.4.1. Blocking or desensitisation

8.4.1.1. Definition

Blocking is a measure of the capability of the receiver to receive a modulated wanted input signal in the presence of an unwanted unmodulated input signal on frequencies other than those of the spurious responses or the adjacent channels, without this unwanted input signal causing a degradation of the performance of the receiver beyond a specified limit.

8.4.1.2. Specifications

The specifications given in ETS 300 113 [4] shall apply.

8.4.2. Spurious response rejection

8.4.2.1. Definition

Spurious response rejection is a measure of the capability of a receiver to receive a wanted modulated signal without exceeding a given degradation due to the presence of an unwanted unmodulated signal at any other frequency at which a response is obtained.

8.4.2.2. Specifications

The specifications given in ETS 300 113 [4] shall apply.

8.4.3. Intermodulation response rejection

8.4.3.1. Definition

Intermodulation response rejection is a measure of the capability of the receiver to receive a wanted modulated signal without exceeding a given degradation due to the presence of two or more unwanted signals with a specific frequency relationship to the wanted signal frequency.

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8.4.3.2. Specifications

The specifications given in ETS 300 113 [4] shall apply.

8.4.4. Unwanted conducted emissions

8.4.4.1. Definition

Unwanted emissions from the equipment in reception are defined as conducted emissions at any frequency, when its transmitter is in standby mode.

8.4.4.2. Specifications

The power emitted by the equipment shall not exceed - 57 dBm at frequencies between 9 kHz and 1 GHz, and - 47 dBm at frequencies from 1 GHz to 4 GHz.

8.4.5. Unwanted radiated emissions

In the case of unwanted radiated emissions the specifications given in ETS 300 113 [4] shall apply.

8.5. Transmitter/receiver performance

Subclause 8.5.1 specifies the phase accuracy of the transmitter. Subclause 8.5.2 specifies the receiver performance, assuming that transmitter errors do not occur. Subclause 8.5.3 specifies all the propagation models that are used in this document.

8.5.1. Phase accuracy

When transmitting frames, the phase accuracy of the signal, relative to the theoretical modulated waveforms as specified in Clause 7, is specified in the following way.

For any 160-bits subsequence of the 511-bits pseudo-random sequence, defined in ITU-T Recommendation O.153 [5], the phase error trajectory on the useful part of the frame shall be measured by computing the difference between the phase of the transmitted waveform and the expected one. The RMS phase error (difference between the phase error trajectory and its linear regression on a frame duration) shall not be greater than 8° with a maximum peak deviation during the useful part of the frame less than 20° outside the ramp-up and ramp-down period.

NOTE: Using the encrypted mode is an allowed means to generate the pseudo-random sequence.

8.5.2. Receiver performance

This subclause specifies the minimum required receiver performance in terms of Bit Error Rate (BER) or Frame Erasure Rate (FER) (whichever is appropriate), taking into account that transmitter errors do not occur, and that the transmitter shall be tested separately.

Error rate performances are specified for the Voice Traffic Channel (VCH). The bits of this channel are subdivided into two classes: class 1 bits are protected and class 2 bits are unprotected. In the following, Frame Erasure occurs when the block of class 1 bits is declared in error by the receiver (FER is defined as the ratio of the number of erased frames to the total number of transmitted frames). Bit Error Rates (BER) are stated for class 2 bits in the accepted frames.

The given received power levels under multipath conditions are the sum of the mean power of the individual paths.

NOTE: Performances given in subclause 8.5.2 are applicable to the UHF case only (300-600 MHz).

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8.5.2.1. Nominal error rates

This subclause describes the transmission requirements in terms of error rates in nominal conditions i.e. without interference and with an input level of - 85 dBm. Relevant propagation conditions are given in subclause 8.5.3.

Under the following propagation conditions, the BER of the class 2 bits of the VCH shall remain below the limits given in table 6.

Table 7: Nominal error rates

logical channel		**propagation condition**	
		static	TU50
VCH class 1	FER	0,005%	
VCH class 2	BER	0,005 %	0,25 %
DCH (data frame)	FER	0,005 %	
DCH (high rate data frames)	FER	0,005 %	

This performance shall be maintained up to - 40 dBm input level for the static conditions, and multipath conditions. Furthermore, for static conditions, the bit error rate shall remain less than 0,1% up to - 20 dBm.

8.5.2.2. Dynamic reference sensitivity performance

The minimum required dynamic reference sensitivity performance is specified according to the propagation condition at the dynamic reference sensitivity level. The dynamic reference sensitivity level shall be:

- for the MS: - 111 dBm;
- for the BS: - 113 dBm.

Tables 7 and 8 give the minimum required dynamic reference sensitivity performance for TU50 or HT200 propagation conditions.

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8.5.2.2.1. BS receiver performance

Table 8: BS receiver performance (dynamic sensitivity)

logical channel		**propagation condition**	
		TU50	HT200
VCH class 1	FER	1 %	1,5 %
VCH class 2	BER	1,5 %	2,5 %
DCH (data frame)	FER		
DCH (high rate data frames)	FER		

8.5.2.2.2. MS receiver performance

Table 9: MS receiver performance (dynamic sensitivity)

logical channel		**propagation condition**	
		TU50	HT200
VCH class 1	FER	1 %	1,5 %
VCH class 2	BER	1,5 %	2,5 %
DCH (data frame)	FER		
DCH (high rate data frames)	FER		

8.5.2.2.3. Reference interference performance

The minimum required reference interference performance (for co-channel, C/Ic, or adjacent channel, C/Ia) is specified according to the propagation condition at the reference interference ratio. The dynamic reference interference ratio shall be, for BS and all types of MS:

- for co-channel interference: C/Ic = 15 dB;
- for adjacent channel interference: C/Ia = - 45 dB (for p=12.5 kHz).

In case of co-channel interference these specifications apply for a wanted input signal level of - 85 dBm, and in case of adjacent channel interference for a wanted input signal level 3 dB above the dynamic reference sensitivity level. In any case the interference shall be a continuous TETRAPOL random modulated signal subject to an independent realisation of the same propagation condition as the wanted signal.

In tables 9 and 10 the minimum required performance for TU100 propagation condition is given for the reference interference level.

8.5.2.2.4. BS receiver performance

Table 10: BS receiver performance (interference)

logical channel		**propagation condition**
		TU100
VCH class 1	FER	2 %
VCH class 2	BER	3 %
DCH (data frame)	FER	
DCH (high rate data frames)	FER	

8.5.2.2.5. MS receiver performance

Table 11: MS receiver performance (interference)

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logical channel		propagation condition TU100
VCH class 1	FER	2 %
VCH class 2	BER	3 %
DCH (data frame)	FER	
DCH (high rate data frames)	FER	

8.5.2.2.6. Static reference sensitivity performance

The static reference sensitivity level shall be:

- for the MS: - 119 dBm;
- for the BS: - 121 dBm.

The following tables 11 and 12 give the minimum required performance at the static reference sensitivity level.

8.5.2.2.7. BS receiver performance

Table 12: BS receiver performance (static sensitivity)

logical channel		
VCH class 1	FER	1 %
VCH class 2	BER	1,5 %
DCH (data frame)	FER	
DCH (high rate data frames)	FER	

8.5.2.2.8. MS receiver performance

Table 13: MS receiver performance (static sensitivity)

logical channel		
VCH class 1	FER	1 %
VCH class 2	BER	1,5 %
DCH (data frame)	FER	
DCH (high rate data frames)	FER	

8.5.2.2.9. Propagation conditions

The following contains all necessary information on the propagation models that are referred to in this document.

8.5.2.3. Simple wideband propagation model

Radio propagation in the mobile radio environment is described by highly dispersive multipath caused by reflection and scattering. The paths between Base Station and Mobile Station may be considered to consist of large reflectors and/or scatterers some distance to the MS, giving rise to a number of waves that arrive in the vicinity of the MS with random amplitudes and delays.

Close to the MS these paths are further randomised by local reflections or diffractions. Since the MS will be moving, the angle of arrival must also be taken into account, since it affects the doppler shift associated with a wave arriving from a particular direction. Echoes of identical delays arise from reflectors located on an ellipse.

The multipath phenomenon described in the following way in terms of the time delays and the doppler shifts associated with each delay:

$$z(t) = \iint_{R^2} y(t-T)S(T,f)\exp(2i\pi fT)dfdT$$

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where the terms on the right-hand side represent the delayed signals, their amplitudes and the doppler spectra.

It has been shown that the criterion for wide sense stationarity is satisfied for distances of about 10 metres. Based on the wide sense stationary uncorrelated scattering (WSSUS) model, the average delay profiles and the doppler spectra are necessary to simulate the radio channel.

In order to allow practical simulation, the different propagation models will be presented here in the following terms:

1) a discrete number of taps, each determined by their time delay and their average power;

2) the Rayleigh distributed amplitude of each tap, varying according to a doppler spectrum S(f).

8.5.2.4. Doppler spectrum types

In this subclause, we define two types of doppler spectra which will be used for the modelling of the channel. Throughout this section the following abbreviations will be used:

f_d = v / λ represents the maximum doppler shift (in Hz), with v (in m/s) representing the vehicle speed, and λ (in m) the wavelength.

The following types are defined:

a) CLASS is the classical doppler spectrum and will be used in all but one case;

(CLASS)

$$S(f) = \frac{A}{\sqrt{1-(f/f_d)^2}} \quad \text{for} \quad -f_d < f < f_d$$

$$S(f) = 0 \quad \text{elsewhere.}$$

b) STATIC is the static propagation model with a constant magnitude. The power density spectrum is defined by:

(STATIC) $S(f) = \delta(f)$

where δ(.) represents the Dirac delta function.

8.5.2.5. Propagation models

In this subclause, the propagation models that are referred to in this document are defined. The vehicle speed x (in km/h), which affects f_d (see above), is attributed to the model designation (e.g. HT200 means Hilly Terrain for 200 km/h).

Table 14: Propagation models

Propagation model	Tap number	Relative delay (µs)	Average relative power (dB)	Doppler spectrum type
Static	1	0	0	STATIC
Typical Urban (TUx)	1	0	0	CLASS
	2	5	- 22,3	CLASS
Hilly Terrain (HTx)	1	0	0	CLASS
	2	15	- 8,6	CLASS

9. Frame Synchronisation

The present Clause defines the frame timing constraints of transmissions on the uplink and downlink.

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9.1. Constraints of frame timing in Network and Repeater Mode

9.1.1. Constraints on Radio Terminal Transmitter

Radio frames are numbered from 0 to 199 with a 4 s period.

Phdown_RT is the time when the first bit in frame N is received at the RT antenna connector in the downlink direction modulo 20 ms, Phup_RT the time when it is transmitted at the RT antenna connector in the uplink direction modulo 20 ms. The uplink frame is present on the radio nearly simultaneously with the downlink frame. A slight timing difference occurs between uplink and downlink frames. This difference shall hold:

$- 800\ \mu s \leq \text{Phup\_RT} - \text{Phdown\_RT} \leq - 600\ \mu s$

9.1.2. Constraints on Base Station Receivers

Phdown_BS is the time when the first bit in frame N is transmitted at the BS antenna connector in the downlink direction modulo 20 ms, Phup_BS the time when it is received at the BS antenna connector in the uplink direction modulo 20 ms. Due to propagation delay and radio terminal timing constraints, the timing difference between uplink and downlink frames at BS shall hold:

$- 800\ \mu s \leq \text{Phup\_BS} - \text{Phdown\_BS} \leq - 600\ \mu s + \text{Propagation delay}$,

where Propagation delay corresponds to the two-way delay from Base Station to Mobile Station. To account for a cell radius of 75 km, the corresponding Propagation delay is approximately 500 µs.

9.2. Direct Mode RT-RT transmissions

There shall be no frame timing synchronisation constraints for direct mode transmissions.

10. Link control

10.1. Base Station Link Control

The value of the Transmitted Power of a BS (TPBS) shall be set at the OMC. Once in service TPBS shall be constant:

TPBS = CELL_TX_PWR

TPBS = CELL_I_TX_PWR if isolated.

10.2. RT Link control

The Transmitted Power of a Terminal (TPT) shall be variable. It shall be calculated by the RT according to local radio conditions. It can vary within fixed limits.

The TPT variation is intended to lower the RT power when it is close to the BS in order to avoid saturation.

The TPT shall be derived from the parameter RXLEV (power level received at the RT) and from the parameter PWR_TX_ADJUST broadcast on the BCH in the SYSTEM_INFO message (see PAS 0001-3-2 [2]).

For RT power setting, the following formula shall hold:

$$\text{TPT} = \max (\text{TPT}_{min} , \min (\text{TPT}_{max}, \text{PWR\_TX\_ADJUST} - \text{RXLEV}))$$

where TPT_{min} is the minimum power that the RT can transmit and TPT_{max} is the maximum power that the RT can transmit.

10.3. Cell threshold

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There shall be two cell threshold values, one for the case of a non-isolated cell, the other for the case of an isolated cell. This parameter RXLEV_ACCESS shall be broadcast in the SYSTEM_INFO message (see PAS 0001-3-2 [2]).

The cell threshold shall be used to reduce the size of a cell or to compensate for the unbalance of link budgets between BS and RT.

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