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Terrestrial Trunked Radio (TETRA); Technical requirements for Direct Mode Operation (DMO); Part 2: Radio aspects

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Contents

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Foreword

This final draft European Standard (EN) has been produced by ETSI Technical Committee Terrestrial Trunked Radio (TETRA), and is now submitted for the ETSI standards One-step Approval Procedure.

The present document is part 2 of a multi-part deliverable covering the Technical requirements for Direct Mode Operation (DMO), as identified below:

Part 1: "General network design";

Part 2: "Radio aspects";

Part 3: "Mobile Station to Mobile Station (MS-MS) Air Interface (AI) protocol";

Part 4: "Type 1 repeater air interface";

Part 5: "Gateway air interface";

Part 6: "Security";

Part 7: "Type 2 repeater air interface"; (Historical)

Part 8: "Protocol Implementation Conformance Statement (PICS) proforma specification"; (Historical)

Part 10: "Managed Direct Mode Operation (M-DMO)". (Historical)

NOTE: Part 7, part 8 and part 10 of this multi-part deliverable are of status "historical" and will not be updated according to this version of the standard.

Proposed national transposition dates	
Date of latest announcement of this EN (doa):	3 months after ETSI publication
Date of latest publication of new National Standard or endorsement of this EN (dop/e):	6 months after doa
Date of withdrawal of any conflicting National Standard (dow):	6 months after doa

1 Scope

This multi-part deliverable defines the Terrestrial Trunked Radio system (TETRA) Direct Mode Operation (DMO). It specifies the basic air interface, the interworking between Direct Mode (DM) groups via repeaters, and interworking with the TETRA Voice plus Data (V+D) system via gateways. It also specifies the security aspects in TETRA DMO, and the intrinsic services that are supported in addition to the basic bearer and teleservices.

The present document applies to the TETRA DMO Mobile Station to Mobile Station (MS-MS), DMO Type 1 repeater and DMO Gateway air interface and contains the specifications of the physical layer according to the OSI seven layer reference model.

It establishes the TETRA DM radio aspects (layer 1 and lower MAC):

- it defines and specifies the modulation;
- it defines and specifies the radio transmission and reception;
- it defines and specifies the synchronization;
- it defines and specifies the channel coding;
- it defines and specifies the channel multiplexing;
- it defines and specifies the control over the radio link.

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.

NOTE: While any hyperlinks included in this clause were valid at the time of publication ETSI cannot guarantee their long term validity.

2.1 Normative references

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

[1] ETSI EN 300 113-1: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Land mobile service; Radio equipment intended for the transmission of data (and/or speech) using constant or non-constant envelope modulation and having an antenna connector; Part 1: Technical characteristics and methods of measurement".

[2] ETSI EN 300 392-2: "Terrestrial Trunked Radio (TETRA); Voice plus Data (V+D); Part 2: Air Interface (AI)".

[3] ETSI EN 300 396-3: "Terrestrial Trunked Radio (TETRA); Technical requirements for Direct Mode Operation (DMO); Part 3: Mobile Station to Mobile Station (MS-MS) Air Interface (AI) protocol".

[4] Void.

[5] ETSI EN 300 396-5: "Terrestrial Trunked Radio (TETRA); Technical requirements for Direct Mode Operation (DMO); Part 5: Gateway air interface".

[6] ETSI EN 300 395-2: "Terrestrial Trunked Radio (TETRA); Speech codec for full-rate traffic channel; Part 2: TETRA codec".

[7] ETSI TS 100 392-15: "Terrestrial Trunked Radio (TETRA); Voice plus Data (V+D); Part 15: TETRA frequency bands, duplex spacings and channel numbering".

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] ETSI Directives: "ETSI Statutes; ETSI Rules of Procedure; ETSI Board Working Procedures; Powers and Functions of the Board; Terms of Reference of the Operational Co-ordination Group (OCG); ETSI Technical Working Procedures; ETSI Drafting rules".

[i.2] ETSI EN 300 392-1: "Terrestrial Trunked Radio (TETRA); Voice plus Data (V+D); Part 1: General network design".

[i.3] Void.

[i.4] ETSI EN 300 396-7: "Terrestrial Trunked Radio (TETRA); Technical requirements for Direct Mode Operation (DMO); Part 7: Type 2 repeater air interface". (Historical).

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in the ETSI Directives [i.1] and the following apply:

Bit Error Ratio (BER): ratio of the bits wrongly received to all bits received in a given logical channel

call transaction: all of the functions associated with a complete unidirectional transmission of information

NOTE: A call is made up of one or more call transactions.

changeover: within a call, process of effecting a transfer of the master role (and hence transmitting MS) at the end of one call transaction so that another can commence

Direct Mode GATEway (DM-GATE): device that provides gateway connectivity between DM-MS(s) and the TETRA TMO network

NOTE 1: The gateway provides the interface between TETRA DMO and TETRA TMO. A gateway may provide only the gateway function (DM-GATE) or may provide the functions of both a DM repeater and a DM gateway during a call (DM-REP/GATE).

NOTE 2: A gateway may have one of three roles on DMO side:

- **master:** if the gateway is either active in a call transaction transmitting traffic or control data, or is reserving the channel by means of channel reservation signalling or during the solicited registration procedure;
- **slave:** if the gateway is receiving traffic and signalling in a call from DM-MS;
- **idle:** if the gateway is not in a call.

Direct Mode Mobile Station (DM-MS): physical grouping that contains all of the mobile equipment that is used to obtain TETRA DM services

NOTE: For synchronization purposes, Direct Mode Mobile Stations may have one of three roles:

- **master:** if the DM-MS is either active in a call transaction transmitting traffic or control data, or is reserving the channel by means of channel reservation signalling and hence is **providing** synchronization information to the channel;

- **slave:** if the DM-MS is receiving traffic and/or signalling in a call transaction and hence is **deriving** synchronization information from the channel.
- **idle:** if the DM-MS is not in a call transaction but may be **deriving** synchronization information from the channel in order to follow the state of the DM channel.

Direct Mode Operation (DMO): mode of simplex operation where mobile subscriber radio units may communicate using radio frequencies which may be monitored by, but which are outside the control of, the TETRA TMO network

NOTE: Direct Mode Operation is performed without intervention of any base station.

Direct Mode REPeater (DM-REP): device that operates in TETRA DMO and provides a repeater function to enable two or more DM-MSs to extend their coverage range

NOTE 1: It may be either a type 1 DM-REP, capable of supporting only a single call on the air interface, or a type 2 DM-REP [i.4], capable of supporting two calls on the air interface. A type 1 DM-REP may operate on either a single RF carrier (type 1A DM-REP) or a pair of duplex-spaced RF carriers (type 1B DM-REP). A type 2 DM-REP operates on a pair of duplex-spaced RF carriers.

NOTE 2: A repeater may have one of two roles:

- **active:** if the repeater is active in a call transaction receiving and transmitting traffic and/or signalling messages;
- **idle:** if the repeater is not in a call.

Direct Mode REPeater/GATEway (DM-REP/GATE): device that combines the functions of a DM repeater and a DM gateway in a single implementation and is capable of providing both functions simultaneously

NOTE: The repeater part of the combined implementation may be either a type 1A repeater, operating on a single DM RF carrier, or a type 1B repeater, operating on a pair of duplex-spaced DM RF carriers.

DM channel: specific grouping of timeslots in the DM multiplex structure related to a particular DM RF carrier (i.e. DM frequency)

NOTE: The grouping may not always be fixed, but in DMO when operating in frequency efficient mode as an example, there are two DM channels, identified by the letters A and B.

DM device: DM-MS, DM-REP, DM-GATE or DM-REP/GATE

Dual mode switchable Mobile Station (DU-MS): MS that is capable to operate in TETRA DMO or in TETRA TMO one mode at a time

NOTE: Only one mode can be selected at any given time and the MS is not capable of monitoring a DM RF carrier while in TMO or a TMO channel while in DMO.

Dual Watch Mobile Station (DW-MS): MS that is either full dual watch MS (F-DW-MS) or idle dual watch MS (I-DW-MS)

NOTE: When idle, the MS periodically monitors both the DM RF carrier and the TMO control channel. If the MS is performing full dual watch, it is also capable of periodically monitoring the TMO control channel while in a DM call and a DM RF carrier while in a TMO call. Alternatively the MS may perform idle dual watch, in which case it need not be capable of monitoring the TMO control channel while involved in a DM activity (e.g. call) or a DM RF carrier while involved in a TMO activity (e.g. call).

frequency efficient mode: mode of operation where two independent DM communications are supported on a single RF carrier

NOTE: In frequency efficient mode the two DM channels are identified as channel A and channel B.

logical channel: any distinct data path

NOTE: Logical channels are considered to operate between logical endpoints.

Message Erasure Rate (MER): ratio of the messages detected as wrong by the receiver to all messages received in a given logical channel

normal mode: mode of operation where only one DM communication is supported on an RF carrier

occupation: time where a call transaction is in progress on a channel

pre-emption: transfer of the master role to the requested DM-MS

NOTE: This process may occur within a call during occupation or to set-up a new call during either occupation or reservation.

Probability of Undetected Erroneous Message (PUEM): limit ratio of the erroneous messages detected as right by the receiver to all messages received in a given logical channel

quarter symbol number: timing of quarter symbol duration 125/9 µs within a burst

radio frequency carrier (RF carrier): radio frequency channel

NOTE: This is a specified portion of the RF spectrum. In DMO, the RF carrier separation is 25 kHz.

reservation: time where a "channel reservation" signal is present on the channel

simplex: mode of working in which information can be transferred in both directions but not at the same time

timebase: device which determines the timing state of signals transmitted by a Direct Mode Mobile Station

timeslot number: counter indicating the timing of timeslots within a DMO frame

Trunked Mode Operation (TMO): mode of operation where MSs communicate via the TETRA V+D air interface which is controlled by the TETRA Switching and Management Infrastructure (SwMI)

NOTE: This is also called V+D operation. The abbreviation "TMO" is used in the present document to pair with the abbreviation "DMO" instead of the abbreviation "V+D". "TMO" abbreviation is not used in EN 300 392-1 [i.2] and EN 300 392-2 [2].

useful part of a burst: part of the burst between and including the symbol time of SN0 and the symbol time of Snmax, with SN0 and Snmax as defined in clause 9 of the present document

3.2 Symbols

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

Ud	Direct Mode air interface
Um	Trunked Mode air interface

3.3 Abbreviations

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

AI	Air Interface
BER	Bit Error Ratio
BN	Bit Number
DLB	Direct mode Linearization Burst
DLL	Data Link Layer
DM-GATE	Direct Mode GATEway
DM-MS	Direct Mode Mobile Station
DMO	Direct Mode Operation
DM-REP	Direct Mode-REPeater
DM-REP/GATE	Direct Mode-REPeater/GATEway
DNB	Direct mode Normal Burst
DQPSK	Differential Quaternary Phase Shift Keying
DR50	DM propagation model Rural area for 50 km/h
DSB	Direct mode Synchronization Burst
DU50	DM propagation model Urban area for 50 km/h
DU-MS	Dual mode (TMO - DMO) switchable Mobile Station

DW-MS	Dual Watch Mobile Station
FN	Frame Number
LCH	Linearization Channel
MAC	Medium Access Control
MER	Message Erasure Rate
mod	modulo (base for counting)
MS	Mobile Station
MS-MS	Mobile Station to Mobile Station
OSI	Open Systems Interconnection
PA	Power Amplifier
PACQ	Probability of synchronization burst ACQuisition
PDF	Probability Density Function
PDS	Power Density Spectrum
PUEM	Probability of Undetected Erroneous Message
QN	Quarter symbol Number
RCPC	Rate-Compatible Punctured Convolutional
RF	Radio Frequency
RMS	Root Mean Square
SCH	Signalling Channel
SN	Symbol Number
SSVE	Sum Square Vector Error
STCH	Stealing Channel
SwMI	Switching and Management Infrastructure
TCH	Traffic Channel
TMO	Trunked Mode Operation
TN	Timeslot Number
V+D	Voice plus Data

4 Radio aspects

4.1 Introduction

Clause 4 is an introduction to the radio aspects of the TETRA DMO standard. It consists of a general description of the organization of the radio-related functions with reference to the clauses where each part is specified in detail. Furthermore, it introduces the reference configuration that will be used throughout the present document.

4.2 Set of logical channels

The radio subsystem provides a certain number of logical channels as defined in clause 9. The logical channels represent the interface between the protocol and the radio.

4.3 Reference configuration

For the purpose of elaborating the specification of the radio-related functions, a reference configuration of the transmission chain is used, as shown in figure 1. Only the transmission part is specified, the receiver being specified only via the overall performance requirements. With reference to this configuration, the clauses address the following functional units:

- clause 5: differential encoding and modulation;
- clause 6: characteristics of transmitter and receiver;
- clause 8: coding, reordering and interleaving, and scrambling;
- clause 9: burst building and logical channel multiplexing;
- clause 10: radio link measurements.

This reference configuration also defines a number of points of vocabulary in relation to the names of bits at different levels in the configuration.

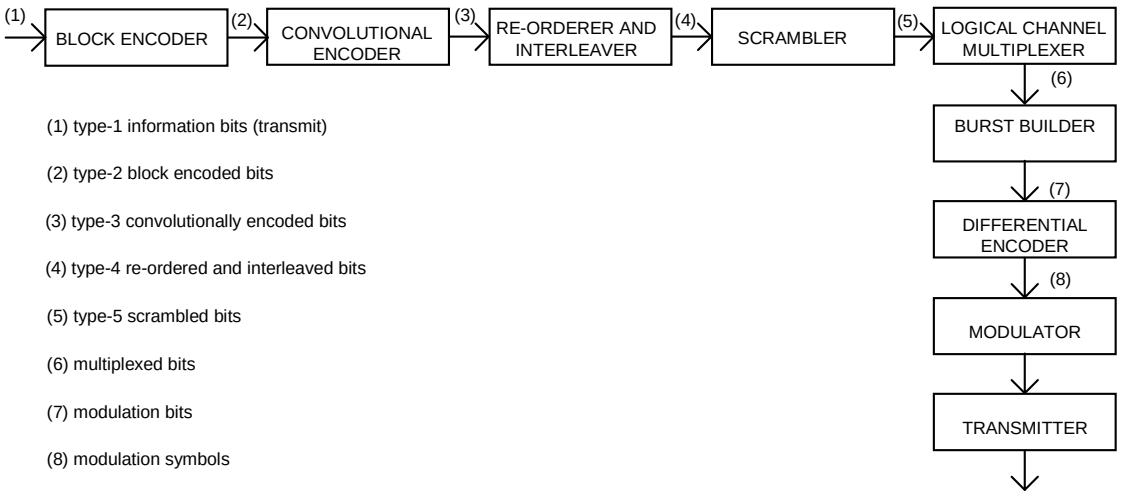


Figure 1: Reference configuration

4.4 Error control schemes

The different error control schemes are described in detail in clause 8.

4.5 Timeslot structure

The carrier separation is 25 kHz.

The basic radio resource is a timeslot lasting 14,167 ms (85/6 ms) and transmitting information at a modulation rate of 36 kbit/s. This means that the timeslot duration, including guard and ramping times, is 510 bit (255 symbol) durations.

The following clauses briefly introduce the structures of multiframes, frames, timeslots and bursts, as well as the mapping of the logical channels onto the physical channels. The appropriate specifications are found in clause 9.

4.5.1 Framing structure

A diagrammatic representation of the framing structure is shown in figure 2.

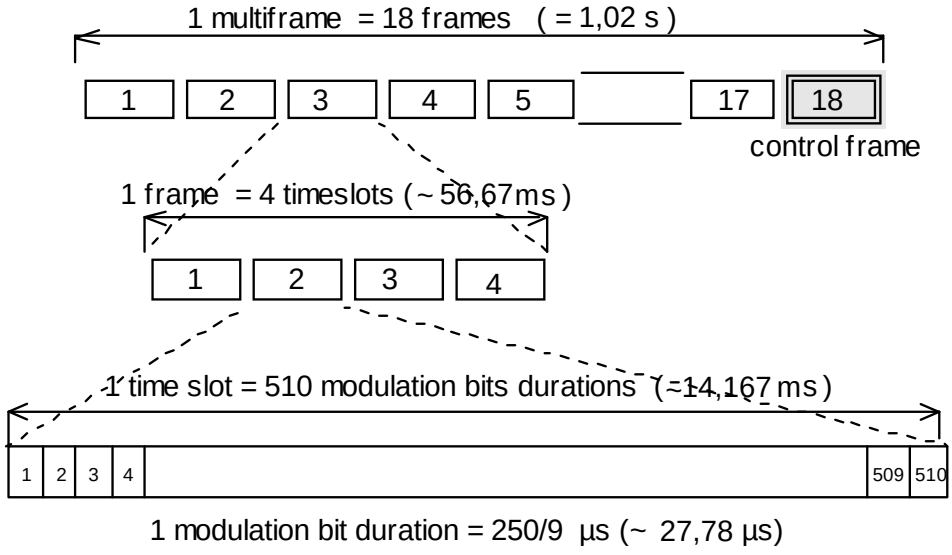


Figure 2: DM framing structure

One multiframe is subdivided into 18 frames, and has a duration of 1,02 s. The eighteenth frame in a multiframe is a control frame.

One frame is subdivided into 4 timeslots, and has a duration of 170/3 ≈ 56,67 ms.

4.5.2 Timeslots and bursts

The timeslot is a time interval of 85/6 ≈ 14,167 ms, which corresponds to 255 symbol durations.

The physical content of a timeslot is carried by a burst. There are three different types of bursts, as defined in clause 9.

4.5.3 Mapping of logical channels onto physical channels

The mapping of the logical channels onto the physical channels, according to the mode of operation, is defined in clause 9.

4.6 Coding, interleaving and scrambling

The coding, interleaving and scrambling schemes associated with each logical channel are specified in clause 8.

4.7 Modulation

The modulation scheme is π/4-DQPSK (Differential Quaternary Phase-Shift Keying) with root-raised cosine modulation filter and a roll-off factor of 0,35. The modulation rate is 36 kbit/s. This scheme is specified in detail in clause 5.

4.8 Transmission and reception

The modulated stream is transmitted on a radio frequency carrier.

The specific RF carrier, together with the requirements on the transmitter and the receiver characteristics are specified in clause 6.

DM device power classes are defined in clause 6.

4.9 Other radio-related functions

Transmission involves other functions. These functions, which may necessitate the handling of specific protocols, are the radio subsystem synchronization, and the radio subsystem link control.

The synchronization incorporates:

- frequency and time acquisition by the receiver;
- adjustment of the timebase in the DM device.

The requirements on synchronization are specified in clause 7.

4.10 Performance

Under typical urban fading conditions the quality threshold for full-rate speech is reached at a C/I_c (co-channel interference) value of 19 dB, and the dynamic reference sensitivity level is -103 dBm for mobile equipment. Details of performance requirements in various channel conditions are given in clause 6.

5 Modulation

5.1 Introduction

The following specifications apply to the baseband part of the transmitter.

5.2 Modulation type

The modulation used shall be π/4-shifted Differential Quaternary Phase Shift Keying (π/4-DQPSK).

5.3 Modulation rate

The modulation rate shall be 36 kbit/s.

5.4 Modulation symbol definition

B(m) denotes the modulation bit of a sequence to be transmitted, where m is the bit number. The sequence of modulation bits shall be mapped onto a sequence of modulation symbols S(k), where k is the corresponding symbol number.

The modulation symbol S(k) shall result from a differential encoding. This means that S(k) shall be obtained by applying a phase transition Dϕ(k) to the previous modulation symbol S(k-1), hence, in complex notation:

$$S(k)=S(k-1)\exp(jD\phi(k))$$

$$S(0)=1 \qquad (1)$$

The above expression for S(k) corresponds to the continuous transmission of modulation symbols carried by an arbitrary number of bursts. The symbol S(0) is the symbol before the first symbol of the first burst and shall be transmitted as a phase reference.

The phase transition Dϕ(k) shall be related to the modulation bits as shown in table 1 and figure 3.

Table 1: Phase transitions

B(2k-1)	B(2k)	Dϕ(k)
1	1	-3π/4
0	1	+3π/4
0	0	+π/4
1	0	-π/4

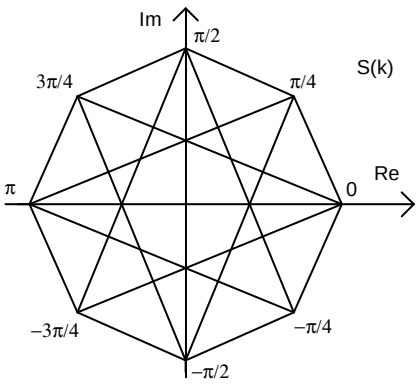


Figure 3: Modulation symbol constellation and possible transitions

The complex modulation symbol S(k) shall take one of the eight values exp(j nπ/4), where n = 2, 4, 6, 8 for even k and n = 1, 3, 5, 7 for odd k. The constellation of the modulation symbols and the possible transitions between them are as shown in figure 3.

5.5 Modulated signal definition

The modulated signal, at carrier frequency f_c, shall be given by:

$$M(t) = \mathrm{Re}\{s(t)\exp(j(2\pi f_c t + \phi_0))\} \quad (2)$$

where:

- ϕ_0 is an arbitrary phase;
- s(t) is the complex envelope of the modulated signal defined as:

$$s(t) = \sum_{k=0}^{K} S(k)\,g(t - t_k) \quad (3)$$

where:

- K is the maximum number of symbols;
- T is the symbol duration;
- t_k = kT is the symbol time corresponding to modulation symbol S(k);
- g(t) is the ideal symbol waveform, obtained by the inverse Fourier transform of a square root raised cosine spectrum G(f), defined as follows:

$$\begin{aligned} G(f) &= 1 && \text{for} && |f| \le (1-\alpha)/2T \\ G(f) &= \sqrt{0{,}5(1-\sin(\pi(2|f|T-1)/2\alpha))} && \text{for} && (1-\alpha)/2T \le |f| \le (1+\alpha)/2T \\ G(f) &= 0 && \text{for} && |f| \ge (1+\alpha)/2T \end{aligned} \quad (4)$$

where α is the roll-off factor, which determines the width of the transmission band at a given symbol rate. The value of α shall be 0,35. For practical implementation, a time limited windowed version of g(t), designed under the constraints given by the specified modulation accuracy and adjacent channel attenuation may be applied.

5.6 Modulation filter definition

The modulation filter shall be a linear phase filter which is defined by the magnitude of its frequency response |H(f)| = G(f).

5.7 Modulation block diagram

A block diagram of the modulation process is shown on figure 4. This diagram is for explanatory purposes and does not prescribe a specific implementation. The modulation filter excited by the complex Dirac impulse function $S(k)\delta(t - t_k)$ ideally has an impulse response g(t).

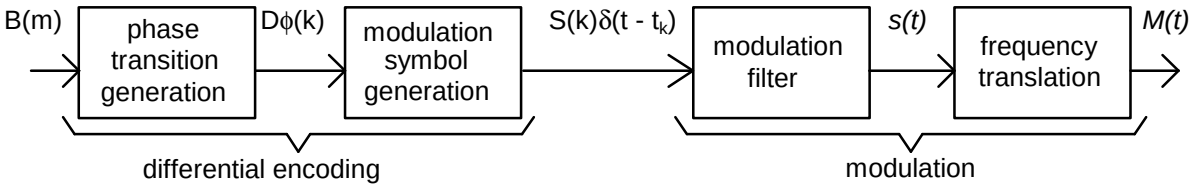


Figure 4: Block diagram of the modulation process

6 Radio transmission and reception

6.1 Introduction

Clause 6 defines the requirements for the DM device transceiver of the TETRA DMO system. Clause 6 is applicable to TETRA systems operating at radio frequencies as defined in TS 100 392-15 [7], clauses 5 and 6.

6.2 Frequency bands and channel arrangement

DM device may only transmit and receive in those RF carriers allocated for TETRA DMO.

For a type 1A DM-REP, all transmission and reception takes place on a single selected DM RF carrier.

For a type 1B DM-REP, transmissions by the DM-MS are received on the appropriate "uplink" RF carrier f_1 while transmissions from the DM-REP are sent on the associated (duplex-spaced) "downlink" RF carrier f_2.

For a DM-GATE or a type 1A DM-REP/GATE, all transmission and reception takes place on a single selected DM RF carrier.

For a type 1B DM-REP/GATE, transmissions by the DM-MSs are received on the appropriate DM "uplink" RF carrier f_1 while transmissions from the DM-REP/GATE are sent on the associated (duplex-spaced) DM "downlink" RF carrier f_2.

Dual Watch Mobile Stations (DW-MSs), Dual Mode Mobile Stations (DU-MSs) and gateways shall also be able to transmit and receive within TETRA TMO.

The TETRA DM RF carrier separation shall be 25 kHz.

6.3 Reference test planes

For the purpose of testing, all DM device 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.

6.4 Transmitter characteristics

6.4.1 Output power

In the following, power is defined as the average power, measured through the square root raised cosine filter defined in clause 5 over the useful part of the burst as defined in clause 9.

A DM-MS may be switched to operate in more than one power class.

6.4.2 Power classes

The nominal DM device transmitting power is defined in "power classes" and shall be, according to its class, as defined in table 2.

Table 2: Nominal power of DM device transmitters

Power class	Nominal power	
1	30 W	45 dBm (note 1)
1L	17,5 W	42,5 dBm (note 1)
2	10 W	40 dBm
2L	5,6 W	37,5 dBm
3	3 W	35 dBm
3L	1,8 W	32,5 dBm
4	1 W	30 dBm
4L	0,56 W	27,5 dBm
5	0,3 W	25 dBm (note 2)
5L	0,18 W	22,5 dBm (note 2)
NOTE 1: Not valid for DM-MS. NOTE 2: Not valid for DM-REP and DM-GATE.		

The power class 1 and 1L shall not be used for a DM-MS.

NOTE: Power class 1 and 1L may not be allowed in some countries.

The power class 5 and 5L shall not be used for DM-REP or DM-GATE other than for testing purpose only.

6.4.3 Unwanted conducted emissions

6.4.3.1 Definitions

Unwanted conducted emissions are defined as conducted emissions at frequencies or time intervals outside the nominal operating channel. The specified limits shall be met under realistic conditions, for instance under varying antenna mismatch.

Unless otherwise stated, unwanted emissions are specified for an equipment in the active transmit state.

A DM device is in the active transmit state whenever it transmits bursts or whenever it ramps-up/linearizes or ramps-down.

The non-active transmit state is a state occurring during two timeslot durations (approximately 28 ms) before and after any active transmit state.

A DM device is said to be in the non-transmit state whenever it is not in the active or non-active transmit state (refer to figure 5).

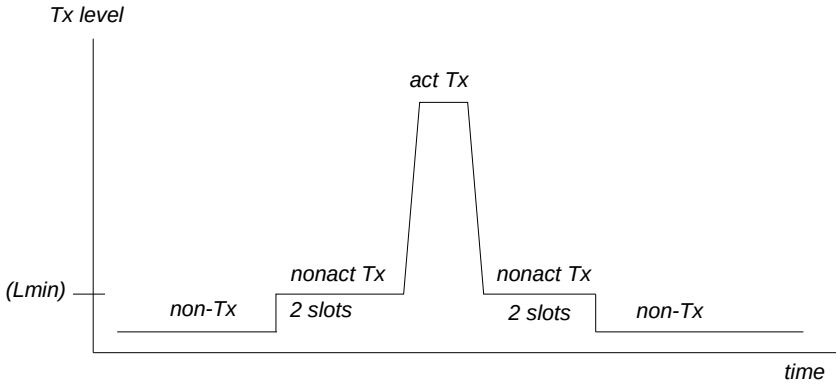


Figure 5: Schematic presentation of transmitter states

6.4.3.2 Unwanted emissions close to the carrier

Unwanted emissions close to the carrier shall be measured through the square root raised cosine filter with a roll-off factor of 0,35 as defined in clause 5.

Measurements shall be carried out at the actual centre frequency and at frequency offsets specified in the following clauses. When applicable, relative measurements (dBc) shall refer to the level measured at the actual centre frequency.

6.4.3.2.1 Emissions during the useful part of the burst

The levels given in tables 3a and 3b, at the listed frequency offsets from the actual carrier frequency, shall not be exceeded.

Table 3a: Maximum adjacent power levels for frequencies below 700 MHz

Frequency offset	Max. level for power classes 4, 4L, 5 and 5L	Max. level for other power classes
25 kHz	-55 dBc	-60 dBc
50 kHz	-70 dBc	-70 dBc
75 kHz	-70 dBc	-70 dBc

In any case, no requirement in excess of -36 dBm shall apply.

Table 3b: Maximum adjacent power levels for frequencies above 700 MHz

Frequency offset	Max. level
25 kHz	-55 dBc
50 kHz	-65 dBc
75 kHz	-65 dBc
NOTE: A level of -70 dBc shall apply for Power Classes 1 and 1L.	

Frequency offset is defined as the difference of the centre measurement frequency from the actual carrier frequency. The measured values shall be averaged over the useful part of the burst (see clause 9). The scrambled bits shall have a pseudo-random distribution from burst to burst.

6.4.3.2.2 Emissions during the switching transients

At the frequency offset from the actual carrier frequency given below, peak power measurements shall be carried out, covering at least the ramp-up period and the ramp-down period (see figure 7, periods t_1 and t_3 and clause 6.4.5 for definition of t_1 and t_3).

The maximum hold level of -45 dBc for DM device power classes 4, 4L, 5 and 5L and -50 dBc for other power classes at a frequency offset of 25 kHz shall not be exceeded. This requirement does not apply to linearization channels.

In any case no requirement in excess of -36 dBm shall apply.

6.4.3.3 Unwanted emissions far from the carrier

These unwanted emissions are emissions (discrete, wideband noise, modulated or un-modulated) occurring at offsets equal to, or greater than, 100 kHz from the carrier frequency, measured in the frequency range 9 kHz to 4 GHz.

6.4.3.3.1 Discrete spurious

The maximum allowed power for each spurious emission shall be less than -36 dBm measured in 100 kHz bandwidth in the frequency range 9 kHz to 1 GHz and -30 dBm measured in 1 MHz bandwidth in the frequency range 1 GHz to 4 GHz (1 GHz to 12,75 GHz for equipment capable of operating at frequencies above 470 MHz). Specific measurement method are required both when measuring within $\pm f_x$ of carrier frequency, due to the presence of wideband noise, and in the lower part of the spectrum.

6.4.3.3.2 Wideband noise

The following wideband noise levels, measured through the modulation filter defined in clause 5.6 should not exceed the limits shown in tables 4a and 4b for the nominal power levels as stated and at the listed offsets from the actual carrier frequency.

Table 4a: DM wideband noise limits for frequencies below 700 MHz

Frequency offset	Maximum wideband noise level (dBc)		
	Nominal power level ≤ 1 W (class 4)	Nominal power level = 3 W or 1,8 W (class 3 or 3L)	Nominal power level ≥ 5,6 W (class 2L)
100 kHz to 250 kHz	-75 dBc	-78 dBc	-80 dBc
250 kHz to 500 kHz	-80 dBc	-83 dBc	-85 dBc
> 500 kHz	-80 dBc	-85 dBc	-90 dBc

Table 4b: DM wideband noise limits for frequencies above 700 MHz

Frequency offset	Maximum wideband noise level (dBc)		
	Nominal power level ≤ 1 W (class 4)	Nominal power levels from 1,8 W to 10 W	Nominal power levels from 15 W to 30 W
100 kHz to 250 kHz	-74 dBc	-74 dBc	-80 dBc
250 kHz to 500 kHz	-80 dBc	-80 dBc	-85 dBc
> 500 kHz	-80 dBc	-85 dBc	-90 dBc

All levels are expressed in dBc relative to the actual transmitted power level.

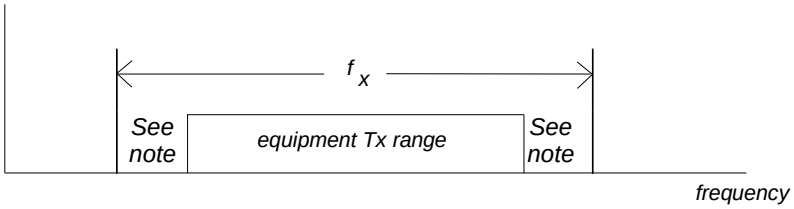
In the case where a DM-device transmits on a DM carrier frequency which is within its normal TMO MS Tx band, then the limits in table 5 shall apply symmetrically to both sides of its TMO MS Tx band.

Table 5: DM wideband noise limits (continued)

Frequency offset (kHz)	Maximum level all classes
> f_{rb}	-100 dBc

Where f_{rb} denotes the frequency offset corresponding to the near edge of its TMO MS receive band with $f_{rb} \geq 5$ MHz (10 MHz for frequencies above 520 MHz).

In other cases, the -100 dBc requirement shall apply outside of the frequency range f_x which comprises the range of frequencies over which the equipment is able to transmit (as declared by the equipment manufacturer), plus a guard band of 5 MHz (10 MHz for frequencies above 520 MHz) on either side as shown in figure 6.



NOTE: 5 MHz (10 MHz for frequencies above 520 MHz).

Figure 6: Definition of f_x

In any case no limit tighter than -55 dBm for offsets < f_{rb} or -70 dBm for offsets > f_{rb} shall apply.

6.4.3.4 Unwanted emissions during the Linearization Channel (LCH)

The sum of the time periods during which the peak power, at a frequency offset of ±25 kHz during the LCH, is above -45 dBc shall not exceed 1 ms. This peak power shall never exceed -30 dBc.

NOTE: 0 dBc refers to the transmit power during normal operation after the LCH.

6.4.3.5 Unwanted emissions in the non-transmit state

The specifications of clause 6.5.4.2 apply.

6.4.4 Unwanted radiated emissions

Unwanted radiated emissions are emissions (whether modulated or un-modulated) radiated by the cabinet and structure of the equipment. This is also known as cabinet radiation.

The limits given in clause 6.4.3.3 shall apply.

6.4.5 Radio frequency tolerance

The radio frequency tolerance for DM devices is defined in clause 7.

6.4.6 RF output power time mask

The transmit level versus time mask for DM device transmissions is shown in figure 7. For the time mask the power level of 0 dBc refers to the output power level of the TETRA station under consideration.

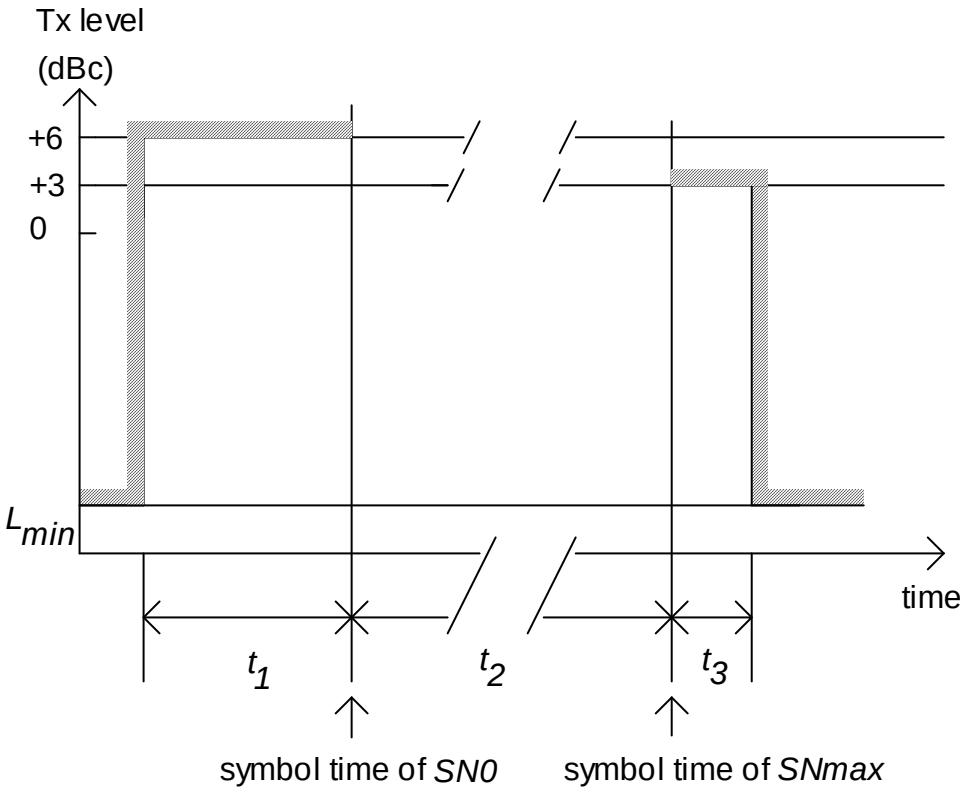


Figure 7: Transmit level versus time mask

Table 6: Transmit level versus time mask symbol durations (refer to figure 7)

Burst Type	t_1	t_2	t_3
Synchronization	16	235 (see note)	15
Linearization	251	-	15
Normal	16	235	15
NOTE: Applies to single slot transmission only.			

Whenever bursts are consecutively transmitted by the same DM device on the same frequency, the transmit level versus time mask applies at the beginning of the transmission of the first burst and at the end of the transmission of the last burst.

The symbol numbers referred to as SN0 and Snmax are defined in clause 9. The timing of the transmitted bursts is specified in clause 7. The time periods t_1, t_2 and t_3, whose durations are stated in table 6, are defined in the following way:

- the time t_1 starts at the beginning of the ramp-up of the first burst, and expires just before the symbol time of SN0;
- the time t_2 starts at the symbol time of SN0 of the first burst and finishes at the symbol time of Snmax of the last burst;
- the time t_3 starts just after the symbol time of Snmax of the last burst and finishes at the end of the ramp-down.

In this clause, the specifications of clauses 6.4.1 and 6.6.1 shall apply during the time t_2. The output power shall be measured through the square root raised cosine filter with a roll off factor of 0,35 as defined in clause 5.

During the non-active transmit state the specification L_{min} = -70 dBc or L_{min} = -36 dBm, whichever is greater, shall apply.

A DM device may be required to receive in slots on the transmit frequency during the non-active transmit state. In this situation the equipment shall meet the receiver sensitivity specifications.

6.4.7 Transmitter intermodulation attenuation

Intermodulation may be caused when a DM device transmits in the close vicinity of the antenna of another DM device.

6.4.7.1 Definition

Transmitter 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.

6.4.7.2 Specification

For a transmitting DM device operating at the nominal power defined by its class, the intermodulation attenuation shall be at least 60 dB for any intermodulation component when measured in 30 kHz bandwidth. The interfering signal shall be unmodulated and have a frequency offset of at least 500 kHz from the carrier frequency. The power level of the interfering signal shall be 50 dB below the power level of the modulated output signal from the transmitter under test.

6.4.7.3 Intra-gateway transmitter intermodulation attenuation

In a DM-REP/GATE implementation, intermodulation may be caused when the gateway transmits simultaneously on the TMO air interface and on the DM air interface.

For all transmitters of a single gateway operating at the maximum allowed power, the peak power of any intermodulation components, when measured in a 30 kHz bandwidth, shall not exceed -60 dBc in the relevant downlink frequency band. In any case no requirement in excess of -36 dBm shall apply.

NOTE: The value of -60 dBc refers to the carrier power measured at the antenna connector of the gateway.

In the case where the performance is achieved by additional internal or external isolating devices (such as circulators) they shall be supplied at the time of conformance testing and shall be used for measurements.

6.5 Receiver characteristics

In clause 6.5, 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.

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

6.5.1 Blocking characteristics

6.5.1.1 Definition

Blocking is a measure of the capability of the receiver to receive a modulated wanted input signal in the presence of an unwanted un-modulated 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.

6.5.1.2 Specification

The blocking performance specification shall apply at all frequencies except those at which spurious responses occur (see clause 6.5.2).

The static reference sensitivity performance as specified in clause 6.6.2.4 shall be met when the following signals are simultaneously input to the receiver:

- a wanted signal at the nominal receive frequency f_o, 3 dB above the static reference sensitivity level as specified in clause 6.6.2.4;
- a continuous sine wave signal at a frequency offset from f_o and level as defined in table 7.

Table 7: Blocking levels of the receiver

Offset from nominal Rx frequency	Level of interfering signal
50 kHz to 100 kHz	-40 dBm
100 kHz to 200 kHz	-35 dBm
200 kHz to 500 kHz	-30 dBm
> 500 kHz	-25 dBm

6.5.2 Spurious response rejection

6.5.2.1 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 un-modulated signal at any other frequency at which a response is obtained, i.e. for which the blocking limit is not met.

6.5.2.2 Specification

The static reference sensitivity performance as specified in clause 6.6.2.4 shall be met when the following signals are simultaneously applied to the receiver:

- a wanted signal at nominal receive frequency f_o, 3 dB above the static reference sensitivity level as specified in clause 6.6.2.4;
- a continuous sine wave signal with any offset from nominal Rx frequency ≥ 50 kHz at a level of -45 dBm.

The number of frequencies within a limited frequency range, defined below, at which the blocking specification of clause 6.5.1.2 is not met shall not exceed 0,05 x (number of frequency channels in the limited frequency range).

The limited frequency range is defined as the frequency of the local oscillator signal f_{lo} applied to the first mixer of the receiver plus or minus the sum of the intermediate frequencies (f_{i1},… f_{in}) and a half of the switching range (sr) of the receiver.

Hence the frequency f_l of the limited frequency range is:

$$f_{lo} - \sum_{j=1}^{n} f_{ij} - sr/2 \le f_l \le f_{lo} + \sum_{j=1}^{n} f_{ij} + sr/2 \qquad (5)$$

where receiver switching range (sr) is the maximum frequency range over which the receiver can be operated without reprogramming or realignment as declared by the manufacturer.

6.5.3 Intermodulation response rejection

6.5.3.1 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 as defined in EN 300 113-1 [1].

6.5.3.2 Specification

The static reference sensitivity performance as specified in clause 6.6.2.4 shall be met when the following signals are simultaneously input to the receiver:

- a wanted signal at the nominal receive frequency f_o, 3 dB above the static reference sensitivity level;
- a continuous sine wave signal at frequency f_1 and with a level of -47 dBm;
- a pseudo-random sequence TETRA modulating a signal at frequency f_2, with a level of -47 dBm, such that $f_o = 2f_1 - f_2$ and $| f_2-f_1 | = 200$ kHz.

6.5.4 Unwanted conducted emissions

6.5.4.1 Definition

Unwanted emissions from the equipment when in reception are defined as conducted emissions at any frequency, when the equipment is in the non-transmit state.

6.5.4.2 Specification

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 (1 GHz to 12,75 GHz for equipment capable of operating at frequencies above 470 MHz), as measured in the bandwidth of 100 kHz.

6.5.5 Unwanted radiated emissions

Unwanted radiated emissions are emissions radiated by the cabinet and structure of the equipment in the non-Tx state. This is also known as cabinet radiation.

The limits given in clause 6.5.4.2 shall apply.

6.6 Transmitter/receiver performance

Clause 6.6.1 specifies the modulation accuracy requirement, by setting limits on the Root Mean Square (RMS) error between the actual transmitted signal waveform and the ideal signal waveform. Clause 6.6.2 specifies the receiver performance, assuming that transmit errors do not occur. Clause 6.6.3 specifies all the propagation models that are defined in the present document.

6.6.1 Modulation accuracy

The specified requirement is vector error magnitude; this does not only take into account modulation filtering linear distortion (amplitude and phase) or modulator impairments (quadrature offset, phase and linear amplitude errors in the modulation symbol constellation) but is a measure of the whole transmitter quality. It also takes into account local oscillator phase noise, filter distortion, and non-linearity of amplifiers. Vector error magnitude shall be specified at symbol time (see clause 6.6.1.2).

6.6.1.1 Ideal case

The modulation symbol s(t) transmitted by an ideal transmitter having a filter impulse response g(t) is defined in clause 5.

Let Z(k) denote the output of an ideal receive filter with impulse response $g \times (-t)\big|_{t=t_k}$. The ideal transmit and receive filters in cascade form a raised cosine Nyquist filter, having a symbol waveform going through zero at symbol duration intervals, so there is no inter-symbol interference at any instant t = t_k, where t_k is the symbol time corresponding to the k-th symbol (as defined in clause 5).

In this case, the output of an ideal receive filter at any instant t_k, stimulated by an ideal transmitter, will be equal to the k-th modulation symbol S(k):

$$Z(k)=s(t)\times g(-t)\big|_{t=t_k}=S(k) \tag{6}$$

In this clause, the numbering of the modulation symbols used is the one defined in clause 9.

6.6.1.2 Vector error magnitude requirement at symbol time

Let Z(k) be the output produced by observing the real transmitter through the ideal receive filter at symbol time t_k. Z(k) is modelled as:

$$Z(k)=\left\{C_0+\left[S(k)+E(k)\right]\right\}C_1W(k) \tag{7}$$

where:

- E(k) is the vector error of modulation symbol S(k);
- W(k) = exp(jkΘ) accounts for a frequency offset giving Θ radians per symbol phase rotation due to transmitter frequency inaccuracy (see clause 7). The possible amplitude variations shall be integrated in the vector error;
- C_0 is a complex constant characterizing the residual carrier;
- C_1 is a complex constant representing the output amplitude and initial phase of the transmitter.

The magnitude of C_0 shall be less than 5 % of the magnitude of S(k). The task of the test receiver is then to:

- estimate the symbol time for processing the receive part;
- estimate the values of C_0, C_1 and Θ. The resulting estimates shall be denoted by C_0', C_1' and Θ′ respectively;
- perform a normalization of the modulation symbol Z(k) accordingly. The modulation symbol that results from this normalization shall be denoted by Z′(k):

$$Z'(k)=\left[Z(k)\exp(-jk\Theta')/C_1'\right]-C_0' \tag{8}$$

With the above notations, the Sum Square Vector Error (SSVE) is defined as:

$$SSVE=\sum_{k=0}^{SN\max}\left|Z'(k)-S(k)\right|^2 \tag{9}$$

where Snmax is the number of symbols in the burst.

The RMS vector error is then computed as the square root of the SSVE divided by the number of symbols in the burst:

$$RMSVE=\sqrt{SSVE/SN\max+1} \tag{10}$$

The RMS vector error in any burst shall be less than 0,1.

The peak vector error magnitude |Z′(k)-S(k)| shall be less than 0,3 for any symbol.

6.6.2 Receiver performance

Clause 6.6.2 specifies the minimum required receiver performance in terms of BER, Message Erasure Rate (MER) or Probability of Undetected Erroneous Message (PUEM) (whichever is appropriate), taking into account that transmitter errors do not occur, and that the transmitter shall be tested separately (see clause 6.6.1).

In clause 6.6.2, the levels of the test signals are given in terms of power levels (dBm) at the antenna connector of the receiver. For the definition of power level refer to clause 6.4.1.

6.6.2.1 Nominal error rates

Clause 6.6.2.1 describes the transmission requirements in terms of error rates in nominal conditions i.e. without interference and with an input level of -85 dBm. The relevant propagation conditions are given in clause 6.6.3.

Under the following propagation conditions, the BER of the non-protected bits, equivalent to the TCH/7,2 shall have the limits given in table 8.

Table 8: Nominal error rates

Propagation model	BER
STATIC	0,01 %
DR50	0,40 %
DU50	0,60 %

This performance shall be maintained up to -40 dBm input level for the static conditions, and multipath conditions. Furthermore, for static conditions, a BER of < 0,1 % shall be maintained up to -20 dBm.

6.6.2.2 Dynamic reference sensitivity

The minimum required dynamic reference sensitivity is specified according to the logical channel, and the propagation condition at the dynamic reference sensitivity level. The dynamic reference sensitivity level for DM devices shall be -103 dBm.

Table 9 gives the maximum permissible DM device receiver MER or BER at the dynamic reference sensitivity level for DU50 and DR50 propagation models.

For Signalling Channel SCH/S, SCH/H and SCH/F, a PUEM < 0,001 % shall be achieved at the dynamic reference sensitivity level.

Table 9: Maximum permissible DM device receiver MER or BER at dynamic reference sensitivity level

Logical channel	Criterion	Propagation Model	
		DU50	DR50
SCH/S	MER	5,60 %	8,00 %
SCH/H	MER	6,40 %	8,00 %
SCH/F	MER	5,40 %	8,00 %
TCH/7,2	BER	1,70 %	2,20 %
TCH/4,8 N = 1	BER	1,50 %	2,00 %
TCH/4,8 N = 4	BER	0,45 %	0,40 %
TCH/4,8 N = 8	BER	0,15 %	0,06 %
TCH/2,4 N = 1	BER	0,37 %	0,35 %
TCH/2,4 N = 4	BER	0,01 %	0,01 %
TCH/2,4 N = 8	BER	0,01 %	0,01 %
STCH	MER	6,40 %	8,00 %
NOTE: N gives the interleaving depth in number of blocks (see clause 8).			

6.6.2.3 Receiver performance at reference interference ratios

The minimum required reference interference ratios are specified according to the logical channel and the propagation condition at the reference interference ratio (for co-channel, C/I_c, or adjacent channel, C/I_a). The reference interference ratio shall be:

- for co-channel interference: C/I_c = 19 dB;
- for adjacent channel interference: C/I_a = -40 dB.

In the case of co-channel interference, these specifications apply for a wanted input signal level of -85 dBm, and in the 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 TETRA random modulated signal subjected to an independent realization of the same propagation condition as the wanted signal.

Table 10 specifies the maximum permissible DM device receiver MER or BER at the reference interference level for DU50 and DR50 propagation conditions.

For SCH/S, SCH/H and SCH/F, a PUEM < 0,001 % shall be achieved at the reference interference level.

Table 10: Maximum permissible DM device receiver MER or BER at reference interference level

Logical channel	Criterion	Propagation Model	
		DU50	DR50
SCH/S	MER	4,90 %	6,00 %
SCH/H	MER	5,60 %	7,00 %
SCH/F	MER	4,80 %	6,50 %
TCH/7,2	BER	1,70 %	2,00 %
TCH/4,8 N = 1	BER	1,60 %	2,00 %
TCH/4,8 N = 4	BER	0,47 %	0,40 %
TCH/4,8 N = 8	BER	0,18 %	0,06 %
TCH/2,4 N = 1	BER	0,45 %	0,35 %
TCH/2,4 N = 4	BER	0,01 %	0,01 %
TCH/2,4 N = 8	BER	0,01 %	0,01 %
STCH	MER	5,60 %	7,00 %
NOTE: N gives the interleaving depth in number of blocks (see clause 8).			

6.6.2.4 Static reference sensitivity

The minimum required static reference sensitivity is specified according to the logical channel and the receiver class at the static reference sensitivity level. For DM devices the static reference sensitivity level shall be -112 dBm.

Table 11 gives the maximum permissible DM devices receiver MER or BER at the static reference sensitivity level.

For SCH/S, SCH/H and SCH/F, a PUEM < 0,001 % shall be achieved at the static reference sensitivity level.

Table 11: Maximum permissible DM device receiver MER or BER at static reference sensitivity level

Logical channel	Criterion	Propagation model
		STATIC
SCH/S	MER	3,00 %
SCH/H	MER	5,00 %
SCH/F	MER	9,00 %
TCH/7,2	BER	4,00 %
TCH/4,8 N = 1	BER	0,30 %
TCH/4,8 N = 4	BER	0,20 %
TCH/4,8 N = 8	BER	0,15 %
TCH/2,4 N = 1	BER	0,01 %
TCH/2,4 N = 4	BER	0,01 %
TCH/2,4 N = 8	BER	0,01 %
STCH	MER	5,00 %
NOTE: N gives the interleaving depth in number of blocks (see clause 8).		

6.6.2.5 Receiver performance for acquisition of synchronization burst

Clause 6.6.2.5 specifies reference sensitivity performance of a DM device receiver for the acquisition of the Direct mode Synchronization Burst (DSB). The performance is defined in terms of the Probability of synchronization burst ACQuisition (PACQ) of detecting a DSB and correctly decoding the SCH information for the condition where the DM device is listening on the frequency while the DSB is transmitted.

Table 12: Receiver performance requirement (probability of correct detection and decoding) for synchronization burst acquisition

Propagation condition	DR50
PACQ	0,8

6.6.3 Propagation conditions

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

6.6.3.1 Tap-gain process types

Clause 6.6.3.1 defines the statistical properties of the stationary complex tap-gain processes, to be applied for the propagation models, in terms of a Probability Density Function (PDF) and a Power Density Spectrum (PDS) which models the Doppler spectrum. The complex tap-gain processes, denoted by a(t) and defined hereunder, are normalized to unity power.

CLASS is the tap-gain process having a PDS equal to the classical Doppler spectrum. The real and imaginary parts of a(t) exhibit an identical Gaussian PDF, an identical PDS and are mutually statistically independent. Hence |a(t)| is Rayleigh distributed. The PDS of a(t) is defined by:

$$S(f) = S_{CLASS}(f, f_d) = \frac{1}{\pi f_d \sqrt{1-(f/f_d)^2}}$$, for $-f_d < f < f_d$; and

$$S(f) = 0$$, elsewhere (11)

where the parameter f_d represents the maximum Doppler shift (in Hz), defined as $f_d = v/\lambda$ with the vehicle speed v (in m/s) and the wavelength λ (in m).

STATIC(f_s) is a tap-gain process with a constant magnitude |a(t)| = 1. The PDS of a(t) is defined by:

$$S(f) = S_{STATIC}(f, f_s) = \delta(f - f_s)$$ (12)

where δ(.) represents the Dirac delta function and f_s the Doppler shift (in Hz).

RICE is a tap-gain process which is the sum process of the two processes CLASS and STATIC(f_s), with $f_s = 0,7\ f_d$, each contributing half of the total power. Hence |a(t)| is Rician distributed and the PDS is:

$$S(f) = S_{RICE}(f, f_d) = 0,5 S_{CLASS}(f, f_d) + 0,5 S_{STATIC}(f, 0,7 f_d) \quad (13)$$

6.6.3.2 DM propagation models

In clause 6.6.2, the propagation models that are referred to in the present document are defined. Two models are used, DU50 and DR50. The vehicle speed x (in km/h), which affects f_d (see clause 6.6.3.1), is attributed to the model designation in the frequency range 380 MHz to 520 MHz (e.g. DU50 means Urban Area for 50 km/h in the 380 MHz to 520 MHz frequency range).

For frequencies outside the 380 MHz to 520 MHz range, for testing purposes only, the vehicle speed in the model is adjusted according the formula:

$$v = 20\ [Hz] \times \lambda\ [m],$$

when DU50 or DR50 is specified to keep the Doppler shift constant relative to 430 MHz.

Table 13: Propagation models

Propagation model	Tap number	Relative delay (μs)	Average relative power (dB)	Tap-gain process
Static	1	0	0	STATIC
Urban Area (Dux)	1	0	0	RICE
Rural Area (DRx)	1	0	0	CLASS

7 Radio sub-system synchronization

7.1 Introduction

Clause 7 defines the requirements for synchronization in TETRA DM Operation, for carrier frequencies as defined in TS 100 392-15 [7], clauses 5 and 6.

7.2 Definitions and general requirements for synchronization of DM device

This clause defines the synchronization requirements of direct DM-MS to DM-MS communication and the DM-MS communication through a type 1 DM-REP and the communication using a DM-GATE.

7.2.1 Synchronisation of DM-MS to DM-MS communication

The DM-MS which provides the initial synchronization reference is defined as the "master" DM-MS. A DM-MS which synchronizes to a "master" DM-MS in order to receive the call transaction is defined as a "slave" DM-MS. A DM-MS which synchronizes to a "master" DM-MS in order to follow the state of the channel, particularly one wishing to pre-empt the call transaction, is defined as an "idle" DM-MS.

At the beginning of a call, during a call transaction or during channel reservation, the master DM-MS shall transmit synchronization bursts to enable any receiving DM-MS on the same channel to synchronize itself in terms of frequency and time, or to maintain synchronization.

In any case a slave or idle DM-MS wishing to transmit shall align its burst transmission to the timeslots and carrier frequency dictated by the transmission of the master DM-MS.

The timebase of a DM-MS shall continuously count quarter symbols, symbols, timeslots and frames, independently of whether the DM-MS is transmitting or not (see clause 7.3). A slave or idle DM-MS is said to be fully time synchronized if all of its timebase counters run synchronously, within a specified tolerance to those of the master DM-MS.

The timing information contained in the SCH/S transmitted by the master DM-MS in the synchronization burst shall refer to the slot and frame number at which the synchronization burst is transmitted. Upon reception of an SCH/S, a slave DM-MS shall use this timing information to set its slot and frame counters and an idle DM-MS shall use this timing information to set its slot and frame counters if it wishes to transmit.

In normal cases (see note 1) a slave or idle DM-MS which becomes the new master DM-MS after a changeover or pre-emption has been carried out successfully shall adopt the state of the timing counters indicated by the old master DM-MS. The transition point at which changeover occurs shall be at a timeslot boundary.

NOTE 1: An exception may be the case where a timing change request has been included within the changeover or pre-emption request.

A master DM-MS which makes a new call on a free DM channel shall begin transmission at the RF carrier frequency resulting from its own frequency reference source.

A DM-MS taking over the master role after changeover or pre-emption shall either:

- begin transmission at the RF carrier frequency resulting from its own frequency reference source; or
- begin transmission at the RF carrier frequency resulting from its synchronization to the previous master and subsequently increment or decrement this transmission frequency in steps of between 25 Hz and 100 Hz until the transmission frequency resulting from its own frequency reference source is reached or until it stops being master. The frequency steps shall be made at a rate of once per frame during occupation and once every 6^{th} frame during reservation. The frequency steps shall not occur during a transmitted burst.

NOTE 2: In occupation, the frequency steps begin with the start of transmission of traffic or, in the case of short data, the transmission of SCH/F frames.

7.2.2 Synchronisation of DM-MS communication through a type 1 DM-REP

In communication through a type 1 DM-REP, the DM-REP provides the frequency synchronization reference. All DM-MSs, including the "master" DM-MS, synchronize in frequency to the DM-REP transmissions. For a type 1A DM-REP, the transmissions take place on the selected DM RF carrier. For a type 1B DM-REP, transmissions from the DM-REP are sent on the "downlink" RF carrier f_2.

A DM-MS which initiates a call defines the initial frequency and timing synchronization. If the DM-REP has been sending signalling on the selected RF carrier, the master DM-MS should take its initial frequency synchronization from this signalling. Otherwise it shall use its own internal free-running reference to generate the carrier as specified in clause 7.2.1.

NOTE 1: Even when the master DM-MS has chosen to synchronize in frequency to the DM-REP prior to sending the call set-up messages, it need not adopt the slot timing or slot and frame numbering defined by the signalling messages from the DM-REP.

At the beginning of a call, the master DM-MS shall transmit its call set-up messages in DSBs. The master DM-MS shall then synchronize in frequency to the DM-REP using the DSBs transmitted by the DM-REP. It shall maintain this frequency synchronization using the DSBs transmitted periodically by the DM-REP. When synchronizing to the DM-REP, the master DM-MS should meet the requirements for the frequency synchronization of a slave DM-MS as specified in clause 7.5.

When the master DM-MS perceives that its transmissions are not adequately synchronized in frequency to the DM-REP's transmissions, it should perform the necessary correction before its next transmitted burst.

NOTE 2: Thus, when the DM-MS perceives that its transmissions are not adequately synchronized in frequency to the DM-REP's transmissions, it performs the complete correction immediately (to within the accuracy specified in clause 7.5).

This includes the case when the DM-MS used its own internal reference to generate the carrier when sending the call set-up DSBs. For example, if the DM-MS is making a call set-up without presence check or sending a fragmented short data message, and it receives its call set-up DSB repeated on the slave link by the DM-REP, then it corrects its frequency synchronization before starting to send the DNBs; or, if it is making a call set-up with presence check, it corrects its frequency synchronization before sending the DM-CONNECT ACK messages.

The DSBs transmitted by the DM-REP at the start of a call and at intervals during the call shall be used by the slave DM-MSs to synchronize themselves in terms of frequency and time, and to maintain synchronization. The DM-MS shall align its burst transmission in time to the timeslots received from the DM-REP, as specified in clause 7.5. It shall also generate the transmission RF carrier using a frequency reference which has been synchronized to the carrier frequency received from the DM-REP, as specified in clause 7.5.

The timebase of a DM-MS shall continuously count quarter symbols, symbols, timeslots and frames, independently of whether the DM-MS is transmitting or not (see clause 7.3). A slave DM-MS is said to be fully time synchronized if all of its timebase counters run synchronously, within a specified tolerance to those of the DM-REP.

NOTE 3: The master DM-MS does not re-align its transmission timing when it receives DSBs from the DM-REP (since the DM-REP follows the slot timing used by the master DM-MS).

The timing information contained in the SCH/S transmitted by the DM-REP in the DSB shall refer to the slot and frame number at which the DSB is transmitted. Upon reception of an SCH/S, the slave DM-MS shall use this timing information to set its slot and frame counters.

In normal cases (see note 4) a slave DM-MS which becomes the new master DM-MS after a changeover or pre-emption has been carried out successfully shall adopt the state of the timing counters used by the previous master DM-MS. The transition point at which changeover occurs shall be at a timeslot boundary.

NOTE 4: An exception may be the case where a timing change request has been included within the changeover or pre-emption request.

The DM-MS taking over the master role shall continue to maintain its frequency synchronization to the DM-REP via the DSBs received from the DM-REP.

7.2.3 Synchronisation of DM-MS communication using a DM-GATE

In gateway communication the gateway provides the synchronization reference for both frequency and time. However, a DM-MS which initiates a call transaction becomes the "master" during the occupation period of that call transaction. All DM-MSs, including a master DM-MS, synchronize (in both frequency and time) to the gateway transmissions. For a DM-GATE or a type 1A DM-REP/GATE, the transmissions take place on the selected DM RF carrier. For a type 1B DM-REP/GATE, transmissions from the gateway are sent on the DM downlink RF carrier f_2.

A DM-MS which initiates a call defines the initial frequency and timing synchronization. If the gateway has been sending signalling on the selected RF carrier, the DM-MS should take its initial frequency and timing synchronization from this signalling. Otherwise it shall use its own internal free-running reference to generate the carrier as specified in clause 7.2 and shall choose a timing arbitrarily.

At the beginning of a call, the calling DM-MS shall transmit its call set-up messages in DSBs. The calling DM-MS shall then synchronize in frequency and time to the gateway using the DSBs transmitted by the gateway. It shall maintain this frequency and time synchronization using the DSBs transmitted periodically by the gateway. When synchronizing to the gateway, the DM-MS should meet the requirements for the synchronization of a slave DM-MS as specified in clause 7.5.

When the DM-MS perceives that its transmissions are not adequately synchronized in frequency to the gateway's transmissions it should perform the necessary correction before its next transmitted burst except when it is sending a short data message. The DM-MS should not alter its frequency synchronization during the transmission of a short data message. If the DM-MS has received DSBs from the gateway during the transmission of (or in response to) the short data message, it may correct its frequency synchronization if it retransmits the short data message. This applies for both unacknowledged and acknowledged short data messages.

A master DM-MS shall re-align its transmission timing if it perceives a difference of more than 1/4 symbol between its own timing and the timing of DSBs received from the gateway. When a master DM-MS requires to adjust its transmission timing, it shall perform the adjustment in steps of 1/4 symbol duration, where each step shall be performed at intervals of not less than 1 multiframe duration and not greater than 3 multiframe durations until the timing difference is less than 1/4 symbol duration.

In determining the timing of signals from the gateway, the timings shall be assessed in such a way that the timing assessment error is less than 1/4 symbol duration.

A DM-MS taking over the master role shall continue to maintain its frequency and time synchronization to the gateway via the DSBs received from the gateway.

Slave DM-MSs in a call synchronize as defined in clause 7.5.

7.2.4 Definitions and general requirements for synchronization of DM-REPs

The DM-REP shall synchronize itself in terms of time to the initial call set-up transmissions from a master DM-MS. Moreover, the DM-REP shall use the timing information contained in the SCH/S transmitted by the master DM-MS to set its slot and frame counters.

The DM-REP shall in its turn transmit DSBs on the slave link to enable timing synchronization of the slave DM-MSs. The timing information contained in the SCH/S transmitted by the DM-REP shall refer to the slot and frame number at which the DSB is transmitted.

NOTE 1: The frame numbering is different on the master and slave links and the DM-REP therefore uses the frame numbering system of the slave link when transmitting its DSBs on that link.

The DM-REP shall generate the transmission carrier using its own internal frequency reference.

NOTE 2: This includes the DM-REP's transmissions of the initial call set-up messages from the master DM-MS, even when the master DM-MS used its own frequency reference to generate the transmission RF carrier. The master DM-MS then synchronizes in frequency to the DM-REP using the DSBs transmitted by the DM-REP. See also clause 7.2.2.

The timebase of a DM-REP shall continuously count quarter symbols, symbols, timeslots and frames, independently of whether the DM-REP is transmitting or not (see clause 7.3).

7.2.5 Definitions and general requirements for synchronization of DM-GATEs

Clause 7.2.1 shall apply, with the following differences.

The gateway shall transmit DSBs on the Ud interface to enable synchronization of the DM-MSs. The timing information contained in the SCH/S transmitted by the gateway shall refer to the slot and frame number at which the DSB is transmitted.

NOTE 1: The gateway synchronizes itself to the TMO base station in the same way as TM-MSs. It then uses the synchronization on the Um interface as a basis for both the frequency and timing on the Ud interface.

NOTE 2: The slot and frame numberings are different on the Um and Ud interfaces and the gateway uses the slot and frame numbering system of the Ud interface when transmitting its DSBs on that interface.

7.3 Timebase counters

7.3.1 Definition of counters

The timing state of the signals transmitted by a DM device shall be defined by the following counters:

- Quarter symbol Number (QN) (1 to 4);

- Symbol Number (SN) (1 to 255);
- Timeslot Number (TN) (1 to 4);
- Frame Number (FN) (1 to 18).

7.3.2 Relationship between the counters

The relationship between these counters shall be as follows:

QN increments every 125/9 µs (unless otherwise required by the slave or idle DM device timebase adjustment) as follows:

$$QN := QN \bmod (4) + 1; \quad (14)$$

SN increments whenever QN changes from 4 to 1 as follows:

$$SN := SN \bmod (255) + 1; \quad (15)$$

TN increments whenever SN changes from 255 to 1 as follows:

$$TN := TN \bmod (4) + 1; \quad (16)$$

FN increments whenever TN changes from 4 to 1 as follows:

$$FN := FN \bmod (18) + 1. \quad (17)$$

The simultaneous change of state of all counters to 1 defines the timebase reference point.

7.4 Requirements for the frequency reference source of DM devices

A DM device shall use a frequency reference source of sufficient accuracy such that the RF carrier frequency is generated to an accuracy of better than ±1,0 kHz.

NOTE: Under many operational circumstances it may be preferable that a DM-REP uses a frequency reference source of sufficient accuracy such that the RF carrier frequency is more accurate than ±1,0 kHz e.g. ±500 Hz.

The timebase shall be clocked to an accuracy of better than ±2 ppm.

7.5 Requirements for the synchronization of a slave or idle DM-MS

The following requirement for carrier frequency and timebase accuracy shall be met by a slave or idle DM-MS for a transmission period of one multiframe duration following initial synchronization. This requirement shall be achieved at receive signal levels greater than or equal to 3 dB below the reference sensitivity level defined in clause 6. Static or dynamic reference sensitivity levels shall be used depending upon the applied propagation conditions:

- whenever the slave or idle DM-MS transmits its carrier frequency, it shall be accurate to within ±250 Hz and its burst timing shall be accurate to within 1/2 symbol period compared to signals received from the master DM device (see note 1).

The following requirement for the carrier frequency and timebase shall be met by a slave or idle DM-MS for the time period following one multiframe duration after initial synchronization until the end of reception of the master's transmission:

- whenever the slave or idle DM-MS transmits its carrier frequency, it shall be accurate to within ±100 Hz and its burst timing shall be accurate to within 1/4 symbol period compared to signals received from the master DM device (see note 1).

The signals received from the master DM device (see note 1) shall be averaged over sufficient time so that errors due to noise, interference or Doppler spread are minimized.

NOTE 1: The master DM device is either a DM-MS or a type 1 DM-REP for operation with a type 1 repeater or a DM-REP/GATE for operation with a repeater/gateway. For operation with a DM-GATE, slave DM-MSs synchronize to the current master (which may be either the DM-GATE or a DM-MS).

NOTE 2: For operation with a type 1B DM-REP, transmissions by DM-MSs are sent on the "uplink" RF carrier f_1.

NOTE 3: When the DM-MS equipment is required to transmit in slave or idle mode, it is important that it synchronizes with and transmits back to the master on the master's frequency and timing. This happens, for example, during pre-emption request, changeover request (when the channel is reserved), timing change request, responding to call set-up with presence check and when responding to an acknowledged short data message.

7.6 Synchronization requirements for a master DM-MS operating on channel B in frequency efficient mode

In frequency efficient operation a master MS operating on channel B shall periodically monitor the channel A master MS transmissions in order to acquire and maintain timing synchronization. The master MS on channel B shall adjust its internal timebase in line with those signals received from the channel A master MS.

The channel B master MS shall meet the following requirements at receive signal levels of greater than or equal to 3 dB below the reference sensitivity level defined in clause 6. Static or dynamic reference sensitivity levels shall be used depending upon the applied propagation conditions.

a) The channel B master MS shall adjust its internal timebase in line with that of signals received from the channel A master MS. If the channel B master MS determines that the timing difference between its current slot timing and that of channel A exceeds 1/4 symbol duration, it shall adjust its timebase in steps of not greater than 1/4 symbol duration. This adjustment shall be performed at intervals of not less than 4y multiframe durations and not greater than 12y multiframe durations until the timing difference is less than 1/4 symbol duration, where the step size is y symbol duration (with $y \leq 1/4$).

NOTE 1: The channel B master MS may adjust its timebase if it detects a timing difference between its current slot timing and that of channel A of less than 1/4 symbol duration.

b) In determining the timing of signals from the channel A master MS, the timings shall be assessed in such a way that the timing assessment error is less than 1/4 symbol duration.

NOTE 2: Channel B operation is not valid for operation with a type 1 DM-REP and a DM-GATE.

7.7 Requirements for the synchronization of a type 1 DM-REP

The DM-REP shall generate the transmission RF carrier using its own internal frequency reference.

The following requirement for timebase accuracy shall be met by the DM-REP for a transmission period of one multiframe duration following initial synchronization to a master DM-MS. This requirement shall be achieved at receive signal levels greater than or equal to 3 dB below the reference sensitivity:

- whenever the DM-REP transmits signalling while a call is ongoing, its burst timing shall be accurate to within 1/2 symbol period compared to signals received from the master DM-MS.

The following requirement for the timebase shall be met by the DM-REP for the time period following one multiframe duration after initial synchronization until the end of the call:

- whenever the DM-REP transmits signalling while a call is ongoing, its burst timing shall be accurate to within 1/4 symbol period compared to signals received from the master DM-MS.

The signals received from the master DM-MS shall be averaged over sufficient time so that errors due to noise, interference or Doppler spread are minimized.

7.8 Requirements for the synchronization of a DM-GATE

When in idle mode, a gateway should be capable of receiving DSBs transmitted with an arbitrary timing and frequency reference. Subsequently, for a call through the gateway, the gateway may change the timing on the Ud interface as described in EN 300 396-5 [5], clause 13.4.7.16.

If it is within range of the SwMI, when transmitting the presence signal and when active in a call, the gateway shall generate the transmission frequency using the synchronization obtained from the Um interface. If the gateway is not within range of the SwMI, when it transmits it shall generate the transmission frequency using its own internal frequency reference. (For example, this may apply if the gateway offers a DM-REP function when it is not within range of the SwMI.)

8 Channel coding and scrambling

8.1 Introduction

A reference configuration of the TETRA transmission chain is given in figure 1. Clause 8 defines the error control process which applies to the information bits (packed in MAC blocks), and which provides multiplexed bits (packed in multiplexed blocks) as shown in figure 1.

Clause 8 applies to all logical channels, however channel coding for speech service is defined in EN 300 395-2 [6], clause 5. The definition of logical channels is given in clause 9.

Clause 8 includes the specification of encoding, re-ordering and interleaving, and scrambling, but does not specify any data processing on the receive part.

A definition of the error control process is provided for each kind of logical channel.

8.2 General

8.2.1 Interfaces in the error control structure

The definition of interfaces within the error control structure is given by figure 8.

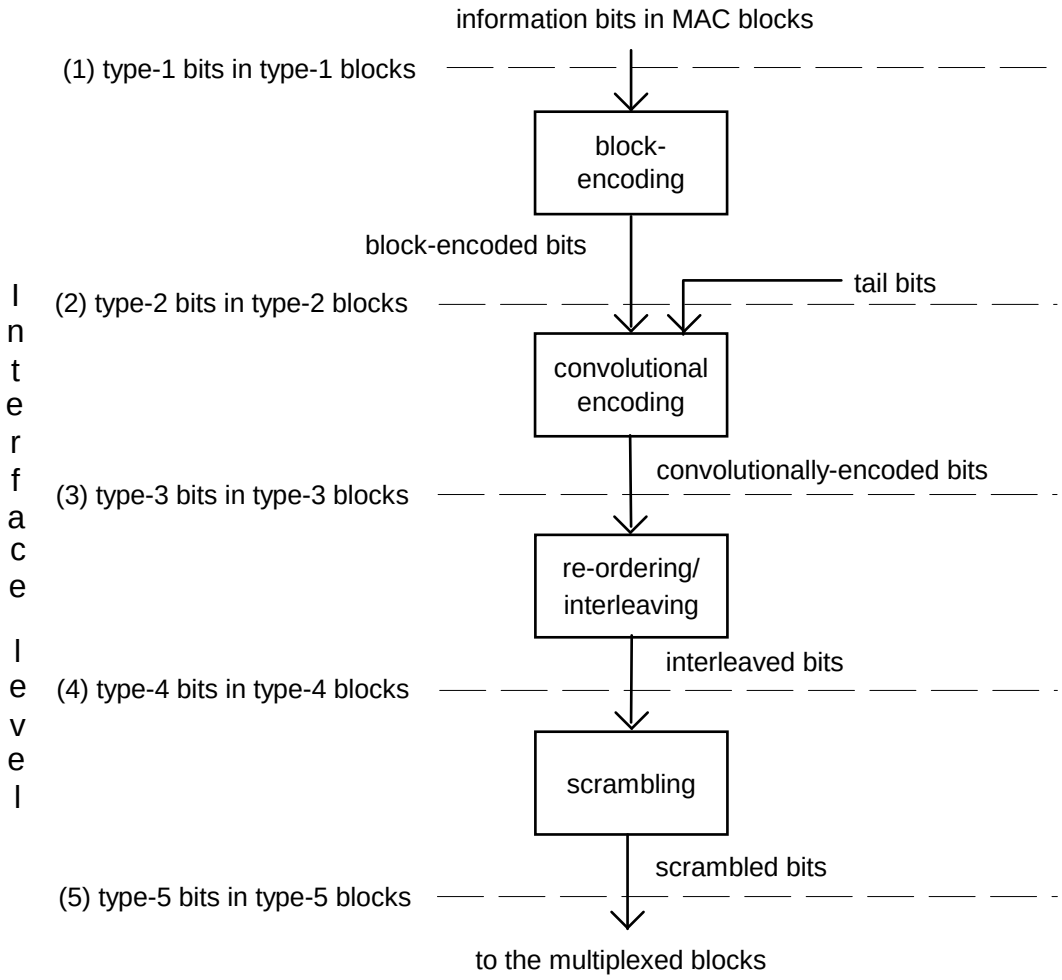


Figure 8: Interfaces in the error control structure

Each logical channel shall have its own error control scheme. For each one, the information bits (eventually including a MAC header) are referred to as type-1 bits. The type-1 bits are packed in MAC blocks, which are referred to as type-1 blocks. This defines interface (1) in figure 8.

The processing in the transmit part shall be as follows:

- The type-1 bits shall be encoded by a block code, providing block-encoded bits. In some cases tail bits shall be appended to these block-encoded bits. The block-encoded bits and the tail bits (if added) are referred to as type-2 bits and shall be packed in a type-2 block. This defines interface (2).
- The type-2 bits shall be encoded by a convolutional code, which provides the convolutionally-encoded bits. The convolutionally-encoded bits are referred to as type-3 bits and shall be packed in a type-3 block. This defines interface (3).
- The type-3 bits shall be reordered and interleaved, into interleaved bits: the interleaved bits are referred to as type-4 bits and shall be packed in encoded blocks. Encoded blocks are referred to as type-4 blocks. This defines interface (4).

- The type-4 bits shall be scrambled, into type-5 bits, which compose type-5 blocks. This defines the interface (5). These bits shall then be mapped into multiplexed blocks. A multiplexed block shall be one of 3 different kinds:
  - synchronization block;
  - block-1 block; or
  - block-2 block.

All these operations are made on a per type-1 block basis. The sizes of type-1 blocks and of type-5 blocks and multiplexed blocks depend on the logical channel with which they are associated.

8.2.2 Notation

For ease of understanding, a notation for bits and blocks is given for use throughout clause 8.2.2:

- x is the interface number, as defined in figure 8: x = 1, 2, 3, 4, 5;
- n is a block number;
- $B_x(n)$ is the type-x block number n;
- K_x is the number of bits that are carried by one type-x block;
- k is a bit number;
- $b_x(n,k)$ is the type-x bit number k in the type-x block number n;
- alternatively $b_x(k)$ is the type-x bit number k in a type-x block (for ease of notation), with k = 1, 2, …, K_x, and n = 1, 2, etc.

The bits of the multiplexed blocks shall be denoted as, accordingly:

- sb(k) is bit number k in a synchronization block;
- bkn1(k) is bit number k in a block-1 block;
- bkn2(k) is bit number k in a block-2 block.

8.2.3 Definition of error control codes

8.2.3.1 16-state Rate-Compatible Punctured Convolutional (RCPC) codes

The RCPC codes shall encode K_2 type-2 bits $b_2(1)$, $b_2(2)$, …, $b_2(K_2)$ into K_3 type-3 bits $b_3(1)$, $b_3(2)$, …, $b_3(K_3)$. This encoding shall be performed in two steps:

- encoding by a 16-state mother code of rate 1/4;
- puncturing of the mother code so to obtain a 16-state RCPC code of rate K_2/K_3.

A general description of these two steps is given in clauses 8.2.3.1.1 and 8.2.3.1.2 respectively. The puncturing coefficients of the 16-state RCPC codes of rates 2/3, 1/3, 292/432 and 148/432 are given in clauses 8.2.3.1.3, 8.2.3.1.4, 8.2.3.1.5 and 8.2.3.1.6 respectively.

8.2.3.1.1 Encoding by the 16-state mother code of rate 1/4

The input to the mother code of any type-2 bit $b_2(k)$, k = 1, 2, …, K_2, implies the output, by the mother code, of 4 bits, denoted by V(4(k - 1) + i), i = 1, 2, 3, 4, which shall be calculated as follows:

- any of the 4 generator polynomials of the mother code, $G_i(D)$, i = 1, 2, 3, 4, can be written as:

$$G_i(D) = \sum_{j=0}^{4} g_{i,j} D^j \quad \text{, for i =1,2,3,4,} \tag{18}$$

where $g_{i,j}$ = 0 or 1, j = 0, 1, 2, 3, 4.

This means that the encoded bits are defined by:

$$V(4(k-1)+i) = \sum_{j=0}^{4} b_2(k-j) g_{i,j} \text{ , for i = 1,2,3,4, and k = 1,2, …, } K_2 \tag{19}$$

where the sum is meant modulo 2, and where $b_2(k - j) = 0$ for $k \leq j$.

The generator polynomials of the mother code shall be:

$$G_1(D) = 1 + D + D^4 \tag{20}$$

$$G_2(D) = 1 + D^2 + D^3 + D^4 \tag{21}$$

$$G_3(D) = 1 + D + D^2 + D^4 \tag{22}$$

$$G_4(D) = 1 + D + D^3 + D^4 \tag{23}$$

8.2.3.1.2 Puncturing of the mother code

The puncturing of the mother code into a 16-state RCPC code of rate (K_2/K_3) is achieved by selecting K_3 type-3 bits out of the (4 K_2) bits encoded by the mother code. This selection shall be as follows.

Denoting by P(1), P(2), …, P(t) the t puncturing coefficients (each one being equal to 1, 2, 3, 4, 5, 6, 7, or 8), the type-3 bits are given by:

$$b_3(j) = V(k) \text{ , for j = 1, 2, …, } K_3, \text{ with } k = 8((i-1) divt) + P(i - t((i-1) divt)), \tag{24}$$

where i and t are defined in the following puncturing schemes.

8.2.3.1.3 Puncturing scheme of the RCPC code of rate 2/3

The t = 3 puncturing coefficients shall be:

$$P(1) = 1, P(2) = 2, P(3) = 5, \text{ and } i = j. \tag{25}$$

8.2.3.1.4 Puncturing scheme of the RCPC code of rate 292/432

The t = 3 puncturing coefficients shall be:

$$P(1) = 1, P(2) = 2, P(3) = 5, \text{ and } i = j + (j - 1) \text{ div } 65, \text{ with } j = 1, 2, \ldots, 432. \tag{26}$$

8.2.3.1.5 Puncturing scheme of the RCPC code of rate 148/432

The t = 6 puncturing coefficients shall be:

P(1) = 1, P(2) = 2, P(3) = 3, P(4) = 5, P(5) = 6, P(6) = 7, and i = j + (j - 1) div 35, with j = 1, 2, …, 432. (27)

8.2.3.2 (K_1 + 16, K_1) block code

The (K_1 + 16, K_1) code shall encode K_1 type-1 bits $b_1(1)$, $b_1(2)$, …, $b_1(K_1)$ into (K_1 + 16) type-2 bits $b_2(1)$, $b_2(2)$, …, $b_2(K_1 + 16)$. The encoding rule shall be as follows:

- the type-1 bits are treated as the coefficients of the polynomial:

$$M(X) = \sum_{k=1}^{K_1} b_1(k) X^{K_1 - k} \tag{28}$$

Let F(X) be:

$$F(X) = \left[\left(X^{16} M(X) + X^{K_1} \sum_{i=0}^{15} X^i \right) \bmod G(X) \right] + \sum_{i=0}^{15} X^i \tag{29}$$

where all operations are meant modulo 2, and G(X) is the generator polynomial of the code:

$$G(X) = X^{16} + X^{12} + X^5 + 1 \tag{30}$$

F(X) is of degree 15, with coefficients denoted by f(0), f(1), …, f(15):

$$F(X) = \sum_{i=0}^{15} f(i) X^i \tag{31}$$

The K_2 type-2 bits, with $K_2 = K_1 + 16$, are then given by:

$b_2(k) = b_1(k)$, for k = 1, 2, ..., K_1; and

$b_2(k) = f(K_1 + 16 - k)$, for k = K_1 + 1, K_1 + 2, ..., K_1 + 16. (32)

8.2.4 Definition of interleaving schemes

8.2.4.1 Block interleaving

A (K,a) block interleaver shall re-order K_3 type-3 bits $b_3(1)$, $b_3(2)$, …, $b_3(K_3)$ into K_4 type-4 bits $b_4(1)$, $b_4(2)$, …, $b_4(K_4)$, with $K = K_3 = K_4$, in the following way:

$b_4(k) = b_3(i)$, i = 1, 2, …, K, with $k = 1 + ((a \times i) \bmod K)$ (33)

8.2.4.2 Interleaving over N blocks

Interleaving over N blocks use two steps to interleave a sequence of M type-3 blocks $B_3(1)$, $B_3(2)$,.. $B_3(M)$ of 432 bits each into a sequence of (M + N - 1) type-4 blocks $B_4(1)$, $B_4(2)$, …, $B_4(M + N - 1)$ of 432 bits each, where M is an integer and N has values 1, 4, or 8. This interleaving shall be as follows.

Firstly, a diagonal interleaver interleaves the M blocks $B_3(1)$, $B_3(2)$,..$B_3(M)$ into (M + N - 1) blocks $B'_3(1)$, $B'_3(2)$,…, $B'_3(M + N - 1)$. Denoting by $b'_3(m,k)$ the k-th bit of block $B'_3(m)$, with k = 1, 2,.., 432 and m = 1, 2, …, M + N - 1,

$b'_3(m,k) = b_3(m - j, j + 1 + (i * N))$, for $1 \le m - j \le M$, (34)

$$b'_3(m,k) = 0 \text{ , otherwise}$$

with j = (k - 1) div (432/N), and i = (k - 1) mod (432/N).

A block interleaver then interleaves each block $B'_3(m)$ into type-4 block $B_4(m)$, m = 1, 2,…, M + N - 1:

$$b_4(m,i) = b'_3(m,k) \text{ ,} \quad (35)$$

with k = 1, 2, …, 432, and i = 1 + ((103 x k) mod 432).

8.2.5 Definition of scrambling

8.2.5.1 Scrambling method

Scrambling shall transform K_4 type-4 bits $b_4(1)$, $b_4(2)$,…, $b_4(K_4)$ into K_5 type-5 bits $b_5(1)$, $b_5(2)$,…, $b_5(K_5)$, with $K_5 = K_4$, as follows:

$$b_5(k) = b_4(k) + p(k) \text{ , for k = 1, 2, …, } K_5, \quad (36)$$

where the addition is meant modulo 2, and p(k) is the k-th bit of the scrambling sequence.

8.2.5.2 Scrambling sequence

The scrambling sequence {p(k), k = 1, 2, …, K_5} shall be generated from the 30 bits of the DM colour code e(1), e(2),.., e(30), except for the SCH/S and SCH/H of the DSB, by means of linear feedback registers. For the scrambling of SCH/S and SCH/H of the DSB, all bits e(1), e(2),.., e(30) shall be set equal to zero.

The scrambling sequence generator shall be based upon the following connection polynomial:

$$c(x) = \sum_{j=0}^{32} c_j X^j \quad (37)$$

with $c_i = 1$ for i = 0, 1, 2, 4, 5, 7, 8, 10, 11, 12, 16, 22, 23, 26 and 32, and $c_i = 0$ elsewhere and where all operations are meant modulo 2. The resultant polynomial is therefore:

$$c(x) = 1 + X + X^2 + X^4 + X^5 + X^7 + X^8 + X^{10} + X^{11} + X^{12} + X^{16} + X^{22} + X^{23} + X^{26} + X^{32} \quad (38)$$

The k-th bit of the scrambling sequence is given by:

$$p(k) = \sum_{j=1}^{32} c_j p(k-j) \quad (39)$$

with the following initialization:

$$p(k) = e(1-k) \text{ , for k = -29, -28, …, 0,}$$

$$p(k) = 1 \text{ , for k = -31, -30.} \quad (40)$$

8.3 Error control schemes

In clause 8.3, the error control scheme associated with each logical channel is defined. Figures 9 and 10 give the error control structure.

8.3.1 Signalling channels

8.3.1.1 Synchronization Signalling Channel (SCH/S)

One type-1 block shall contain 60 type-1 bits $b_1(1)$, $b_1(2)$, …, $b_1(60)$.

A (76,60) block code shall encode the 60 type-1 bits into 76 block-encoded bits, $b_2(1)$, $b_2(2)$, …, $b_2(76)$. This code is the $(K_1 + 16, K_1)$ block code as defined in clause 8.2.3.2, with $K_1 = 60$.

Four tail bits, $b_2(77)$, $b_2(78)$, $b_2(79)$, $b_2(80)$, all set equal to zero, shall be appended to the 76 block-encoded bits.

The resultant bits $b_2(1)$, $b_2(2)$, …, $b_2(80)$ shall be the type-2 bits.

A 16-state RCPC code with rate 2/3 (see clause 8.2.3.1), shall encode the 80 type-2 bits into 120 type-3 bits, $b_3(1)$, $b_3(2)$, …, $b_3(120)$.

A (120, 11) block interleaving (see clause 8.2.4.1) shall re-order the 120 type-3 bits into 120 type-4 bits, $b_4(1)$, $b_4(2)$, …, $b_4(120)$.

The 120 type-4 bits, $b_4(1)$, $b_4(2)$, …, $b_4(120)$ compose the type-4 block for SCH/S. They shall be scrambled into bits $b_5(1)$, $b_5(2)$, …, $b_5(120)$, according to clause 8.2.5.1, with the scrambling sequence as defined in clause 8.2.5.2.

The multiplexed bits of the synchronization block shall be defined as:

$$sb(k) = b_5(k) \text{ , for k = 1, 2, …, 120.} \quad (41)$$

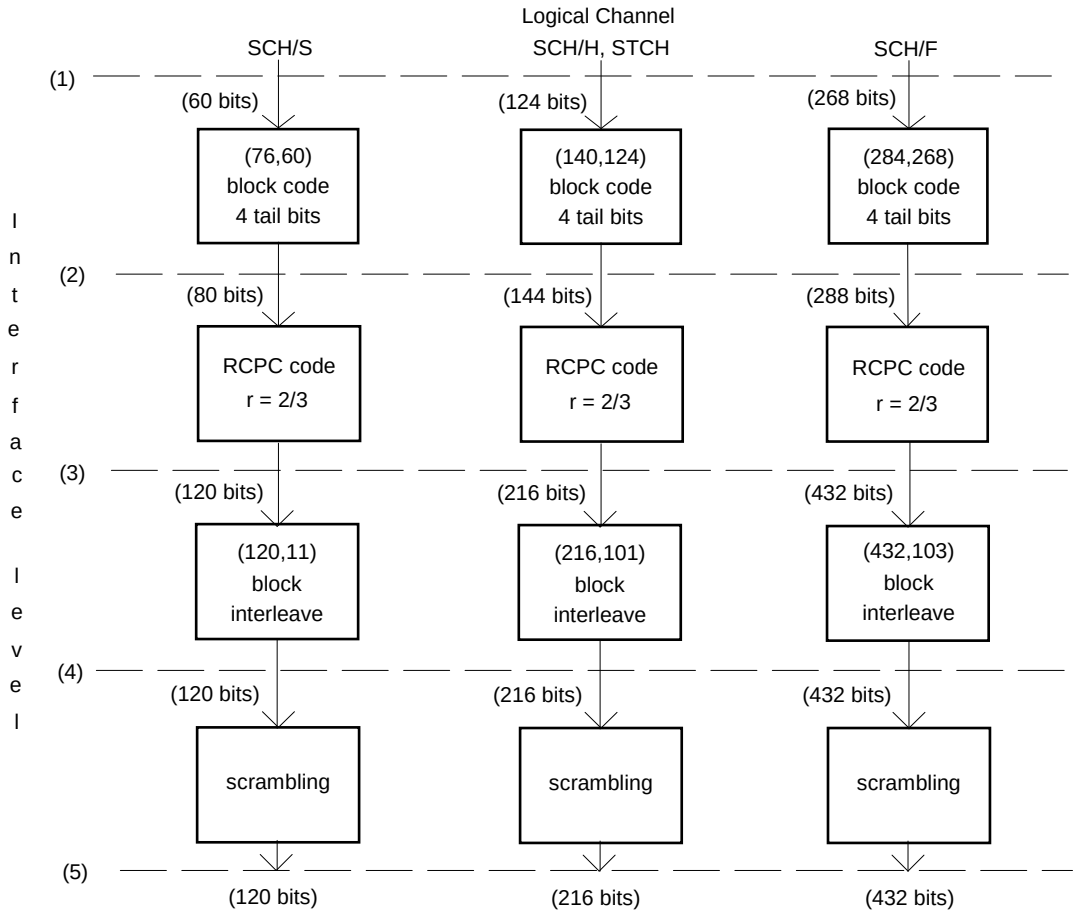


Figure 9: Error control structure for DM logical channels (part 1)

8.3.1.2 Half-slot Signalling Channel (SCH/H) and Stealing Channel (STCH)

One type-1 block shall contain 124 type-1 bits, $b_1(1)$, $b_1(2)$, …, $b_1(124)$.

A (140,124) block code shall encode the 124 type-1 bits into 140 block-encoded bits $b_2(1)$, $b_2(2)$, …, $b_2(140)$. This code shall be the $(K_1 + 16, K_1)$ block code as defined in clause 8.2.3.2, with $K_1 = 124$.

Four tail bits, $b_2(141)$, $b_2(142)$, $b_2(143)$, $b_2(144)$, all set equal to zero, shall be appended to the 140 block-encoded bits.

The resultant bits $b_2(1)$, $b_2(2)$, …, $b_2(144)$ shall be the type-2 bits.

A 16-state RCPC code with rate 2/3 (see clause 8.2.3.1) shall encode the 144 type-2 bits into 216 type-3 bits, $b_3(1)$, $b_3(2)$, …, $b_3(216)$.

A (216,101) block interleaver (see clause 8.2.4.1) shall re-order the 216 type-3 bits into 216 type-4 bits, $b_4(1)$, $b_4(2)$, …, $b_4(216)$.

The 216 type-4 bits $b_4(1)$, $b_4(2)$, …, $b_4(216)$ shall compose the type-4 block for SCH/H and STCH. They shall be scrambled into bits $b_5(1)$, $b_5(2)$, …, $b_5(216)$, according to clause 8.2.5.1, with the scrambling sequence as defined in clause 8.2.5.2.

The type-5 bits may be multiplexed onto block-1, in which case the multiplexed bits are defined as:

$$bkn1(k) = b_5(k) \text{ , for k = 1, 2, …, 216,} \quad (42)$$

or they may be multiplexed into block-2, in which case the multiplexed bits shall be defined as:

$$bkn2(k) = b_5(k) \text{ , for k = 1, 2, …, 216.} \quad (43)$$

8.3.1.3 Full-slot Signalling Channel (SCH/F)

One type-1 block shall contain 268 type-1 bits, $b_1(1)$, $b_1(2)$, …, $b_1(268)$.

A (284,268) block code shall encode the 268 type-1 bits into 284 block-encoded bits $b_2(1)$, $b_2(2)$, …, $b_2(284)$. This code shall be the $(K_1 + 16, K_1)$ block code as defined in clause 8.2.3.2, with $K_1 = 268$.

Four tail bits, $b_2(285)$, $b_2(286)$, $b_2(287)$, $b_2(288)$, all set equal to zero, shall be appended to the 284 block-encoded bits.

The resultant bits $b_2(1)$, $b_2(2)$, …, $b_2(288)$ shall be the type-2 bits.

A 16-state RCPC code with rate 2/3 (see clause 8.2.3.1) encodes the 288 type-2 bits into 432 type-3 bits, $b_3(1)$, $b_3(2)$, …, $b_3(432)$.

A (432,103) block interleaver (see clause 8.2.4.1) shall re-order the 432 type-3 bits into 432 type-4 bits, $b_4(1)$, $b_4(2)$, …, $b_4(432)$.

The 432 type-4 bits $b_4(1)$, $b_4(2)$, …, $b_4(432)$ shall compose the type-4 block for SCH/F. They shall be scrambled into bits $b_5(1)$, $b_5(2)$, …, $b_5(432)$, according to clause 8.2.5.1, with the scrambling sequence as defined in clause 8.2.5.2.

The multiplexed bits of block-1 are defined as:

$$bkn1(k) = b_5(k) \text{ , for k = 1, 2, …, 216} \quad (44)$$

and the multiplexed bits of block-2 are defined as:

$$bkn2(k) = b_5(k + 216) \text{ , for k = 1, 2, …, 216.} \quad (45)$$

8.3.2 Traffic channels in circuit switched mode

In case frame stealing is activated for one of the data traffic channels defined below the multiplexed bits either of block-1 or of block-1 and block-2 are replaced by STCH bits. This means that the bits are replaced after coding, interleaving and scrambling. The construction of STCH bits is defined in clause 8.3.1.2.

NOTE: Frame stealing on speech traffic channels modifies the type of logical channel which the speech channel encoder is using, refer to EN 300 395-2 [6], clause 5 and notes in clauses 8.3.2.4 and 8.3.2.5.

8.3.2.1 Traffic channel, net rate = 7,2 kbit/s (TCH/7,2)

A sequence of M type-1 blocks, $B_1(m)$, m = 1, 2,…, M, shall be transmitted, whereby M is not limited.

One type-1 block shall contain 432 type-1 bits, $b_1(1)$, $b_1(2)$,…, $b_1(432)$.

There shall be 432 type-4 bits, which are the same as the type-1 bits:

$$b4(k) = b1(k), \text{ for } k = 1, 2,\ldots, 432. \quad (46)$$

The 432 type-4 bit $b_4(1)$, $b_4(2)$,…, $b_4(432)$ shall compose the type-4 block for TCH/7,2. They shall be scrambled into bits $b_5(1)$, $b_5(2)$,…, $b_5(432)$, according to clause 8.2.5.1, with the scrambling sequence as defined in clause 8.2.5.2.

The multiplexed bits of block-1 shall be defined as:

$$bkn1(k) = b5(k), \text{ for } k = 1, 2,..., 216. \quad (47)$$

In case of frame stealing of block-1 *bkn1(1), bkn1(2),…, bkn1(216)* shall be discarded, and replaced with the STCH bits as defined in 8.3.1.2 for block-1.

The multiplexed bits of block-2 shall be defined as:

$$bkn2(k) = b_5(k + 216), \text{ for } k = 1, 2,..., 216. \quad (48)$$

In case of frame stealing of block-2, *bkn2(1),bkn2(2),…, bkn2(216*) shall be discarded, and replaced with the STCH bits as defined in 8.3.1.2 for block-2.

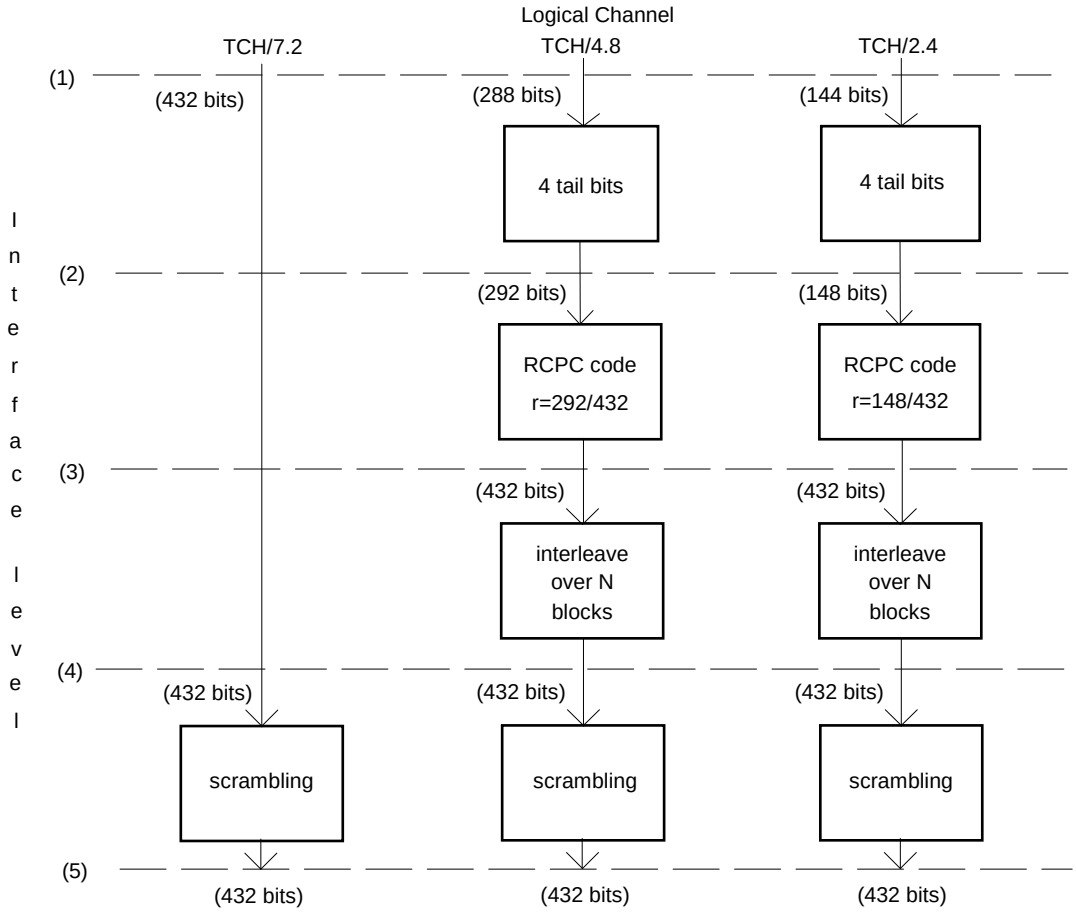


Figure 10: Error control structure for DM logical channels (part 2)

8.3.2.2 Traffic channel, net rate = 4,8 kbit/s (TCH/4,8)

A sequence of M type-1 blocks, $B_1(m)$, m = 1, 2,…, M, shall be transmitted, whereby M is not limited.

One type-1 block shall contain 288 type-1 bits, $b_1(1)$, $b_1(2)$,…, $b_1(288)$.

The K_2 = 292 type-2 bits shall comprise the 288 type-1 bits mapped as follows:

$$b2(j) = b1(j), \text{ for } j = 1, 2,\ldots, 288. \quad (49)$$

with the addition of four tail bits, $b_2(289)$, $b_2(290)$, $b_2(291)$, $b_2(292)$, all set equal to zero.

A 16-state RCPC code with rate 292/432 (see clause 8.2.3.1) shall encode the 292 type-2 bits into 432 type-3 bits, $b_3(1)$, $b_3(2)$,…, $b_3(432)$.

An interleaving over N blocks (see clause 8.2.4.2) shall interleave bits from M type-3 blocks (of 432 bits each) into (M + N - 1) type-4 blocks (of 432 bits each): the bits in one type-4 block shall be denoted by $b_4(1)$, $b_4(2)$,…, $b_4(432)$. The parameter N shall be pre-set at the call set-up, and may take the values 1, 4 or 8.

The 432 type-4 bits $b_4(1)$, $b_4(2)$,…, $b_4(432)$ shall compose the type-4 block for TCH/4,8. They shall be scrambled into bits $b_5(1)$, $b_5(2)$,…, $b_5(432)$, according to clause 8.2.5.1, with the scrambling sequence as defined in clause 8.2.5.2.

The multiplexed bits of block-1 are defined as:

$$bkn1(k) = b_5(k), \text{ for } k = 1, 2,..., 216. \quad (50)$$

In case of frame stealing of block-1 *bkn1(1), bkn1(2),…, bkn1(216)* shall be discarded, and replaced with the STCH bits as defined in clause 8.3.1.2 for block-1.

The multiplexed bits of block-2 are defined as:

$$bkn2(k) = b_5(k + 216), \text{ for } k = 1, 2,..., 216. \quad (51)$$

In case of frame stealing of block-2, *bkn2(1),bkn2(2),…, bkn2(216*) shall be discarded, and replaced with the STCH bits as defined in clause 8.3.1.2 for block-2.

8.3.2.3 Traffic channel, net rate = 2,4 kbit/s (TCH/2,4)

A sequence of M type-1 blocks, $B_1(m)$, m = 1, 2,…, M, shall be transmitted, whereby M is not limited.

One type-1 block shall contain 144 type-1 bits, $b_1(1)$, $b_1(2)$,…, $b_1(144)$.

The $K_2 = 148$ type-2 bits shall comprise the 144 type-1 bits mapped as follows:

$$b_2(j) = b_1(j), \text{ for } j = 1, 2,..., 144, \quad (52)$$

with the addition of four tail bits, $b_2(145)$, $b_2(146)$, $b_2(147)$, $b_2(148)$, all set equal to zero.

A 16-state RCPC code with rate 148/432 (see clause 8.2.3.1) encodes the 148 type-2 bits into 432 type-3 bits, $b_3(1)$, $b_3(2)$,…, $b_3(432)$.

An interleaving over N blocks (see clause 8.2.4.2) shall interleave bits from M type-3 blocks (of 432 bits each) into (M + N - 1) type-4 blocks (of 432 bits each): the bits in one type-4 block shall be denoted by $b_4(1)$, $b_4(2)$,…, $b_4(432)$. The parameter N shall be pre-set at the call set-up, and may take the values 1, 4 or 8.

The 432 type-4 bits $b_4(1)$, $b_4(2)$,…, $b_4(432)$ shall compose the type-4 block for TCH/2,4. They shall be scrambled into bits $b_5(1)$, $b_5(2)$,…, $b_5(432)$, according to clause 8.2.5.1, with the scrambling sequence as defined in clause 8.2.5.2.

The multiplexed bits of block-1 are defined as:

$$bkn1(k) = b_5(k), \text{ for } k = 1, 2,..., 216. \quad (53)$$

In case of frame stealing of block-1 *bkn1(1), bkn1(2),…, bkn1(216)* shall be discarded, and replaced with the STCH bits as defined in clause 8.3.1.2 for block-1.

The multiplexed bits of block-2 are defined as:

$$bkn2(k) = b_5(k + 216), \text{ for } k = 1, 2,..., 216. \quad (54)$$

In case of frame stealing of block-2, *bkn2(1),bkn2(2),…, bkn2(216*) shall be discarded, and replaced with the STCH bits as defined in clause 8.3.1.2 for block-2.

8.3.2.4 Speech Traffic Channel, full slot (TCH/S)

EN 300 395-2 [6] defines in clause 5.5.3, 432 type-4 bits $C_4(1), C_4(2),…, C_4(432)$. For the purpose of scrambling, those bits are mapped into $b_4(k) = C_4(k)$ *for* $k = 1,2,…,432$. The $b_4(1), b_4(2),…, b_4(432)$ bits shall be scrambled into bits $b_5(1), b_5(2),…, b_5(432)$, according to clause 8.2.5.1, with the scrambling sequence as defined in clause 8.2.5.2.

The multiplexed bits of block-1 shall be defined as:

$bkn1(k) = b_5(k)$, for $k = 1, 2,..., 216$,

and the multiplexed bits of block-2 shall be defined as:

$bkn2(k) = b_5(k + 216)$, for $k = 1, 2,..., 216$.

NOTE: It is considered that the MS is not stealing from a full slot speech channel but the MAC first informs the speech channel encoder which discards the type-1 bits of speech frame A and then uses half slot speech channel encoding for the type-1 bits of speech frame B.

8.3.2.5 Speech Traffic Channel, half slot (TCH/S)

EN 300 395-2 [6] defines in clauses 5.4.3.2, 5.6.2 and 5.6.2.1, 216 type-3 bits $C_3(1), C_3(2),\ldots, C_3(216)$. For the purpose of further processing, those bits are mapped into $b_3(k) = C_3(k)$ *for* $k = 1, 2,\ldots, 216$.

As specified in EN 300 395-2 [6] clause 5.6.3, a (216, 101) block interleaver (see clause 8.2.4.1) shall re-order the 216 type-3 bits $b_3(1), b_3(2),\ldots, b_3(216)$, into 216 type-4 bits, $b_4(1), b_4(2),\ldots, b_4(216)$.

The 216 type-4 bits $b_4(1), b_4(2),\ldots, b_4(216)$ shall compose the type-4 block for the half slot speech channel. They shall be scrambled into bits $b_5(1), b_5(2), \ldots, b_5(216)$, according to clause 8.2.5.1, with the scrambling sequence as defined in clause 8.2.5.2.

The multiplexed bits of block-2 shall be defined as:

$bkn2(k) = b_5(k)$, for $k = 1, 2,..., 216$.

NOTE: The MAC does not use block-1 for half slot speech transmission.

9 Channel multiplexing for DM

9.1 Introduction

Clause 9 defines the physical channels of the DM radio sub-system required to support the logical channels. It includes a description of the logical channels and the definitions of DM frames, timeslots and bursts.

9.2 Logical channels

A logical channel is defined as a logical communication pathway between two or more parties. The logical channels represent the interface between the protocol and the radio subsystem.

The definition of the logical channels that are supported by the radio subsystem is given below.

9.2.1 Logical channels hierarchy

The logical channels may be separated into two categories: the traffic channels carrying speech or data information in circuit switched mode and the control channels carrying signalling. The logical channels supported by the DLL are described here, with their hierarchical relationship.

9.2.2 Traffic channels

The traffic channels shall carry user information. Different traffic channels are defined for speech or data applications and for different data message speeds:

- speech traffic channel (TCH/S);
- circuit mode data traffic channels;
  - 7,2 kbit/s net rate (TCH/7,2);
  - 4,8 kbit/s net rate (TCH/4,8);
  - 2,4 kbit/s net rate (TCH/2,4).

Three different depths of interleaving (with N = 1, 4, or 8) may be applied to the traffic channels TCH/4,8 and TCH/2,4 as detailed in clause 8.2.4.2.

9.2.3 Control channels

9.2.3.1 General

There are three categories of control channel defined for DM:

- linearization;
- signalling; and
- stealing channels.

9.2.3.2 Linearization Channel (LCH)

The LCH shall be used by the mobile stations to linearize their transmitters.

9.2.3.3 Signalling Channel (SCH)

The SCH may carry messages specific to one or one group of mobile stations. There are three categories of SCH:

- Synchronization Signalling Channel (SCH/S) used for synchronization messages;
- Half slot Signalling Channel (SCH/H) used in the half slot following SCH/S;
- Full slot Signalling Channel (SCH/F) used for Short Data messages.

9.2.3.4 Stealing Channel (STCH)

The STCH is a channel associated to a TCH that temporarily "steals" a part of the associated TCH capacity to transmit control messages. It may be used when fast signalling is required.

9.3 The physical resource

9.3.1 General

The physical resource available to the radio sub-system is an allocation of part of the radio spectrum. The radio spectrum allocation shall be partitioned into radio frequency carriers with each radio frequency carrier partitioned in time into multiframes, frames and timeslots as shown in figure 11.

All DM-MSs in a call shall transmit and receive on the same radio frequency carrier.

A type 1A DM-REP shall transmit and receive on the same RF carrier. A type 1B DM-REP shall receive on the "uplink" RF carrier f_1 and transmit on the "downlink" RF carrier f_2.

A DM-GATE or a type 1A DM-REP/GATE shall transmit and receive on the same RF carrier, A type 1B DM-REP/GATE shall receive on the DM "uplink" RF carrier f_1 and transmit on the DM "downlink" RF carrier f_2.

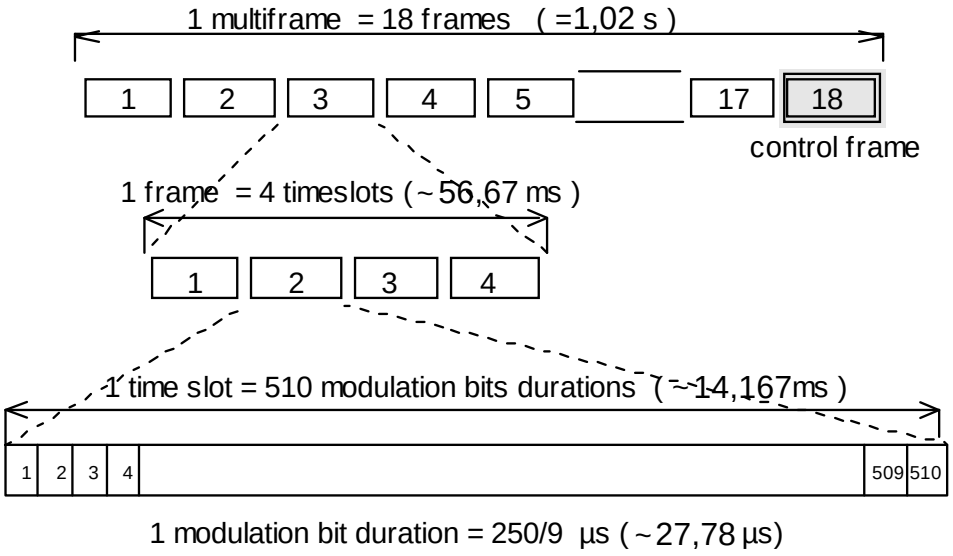


Figure 11: DM frame structure

9.3.2 Timeslots

A timeslot shall have a duration of 85/6 ms (approximately 14,17 ms) which corresponds to 510 modulation bits duration.

The timeslots within a DM frame shall be numbered by timeslot number (TN) 1 to 4.

9.3.3 DM frame

Four timeslots shall form a DM frame. The DM frame has a duration of 170/3 ms (approximately 56,67 ms).

The DM frames shall be numbered by a Frame Number (FN). FN shall be cyclically numbered from 1 to 18. FN shall be incremented at the end of each DM frame. The frame FN18 shall be exclusively devoted to signalling channels.

9.3.4 Multiframe

Eighteen frames shall form a multiframe. The multiframe shall have a duration of 1,02 s.

For a type 1A DM-REP, the start of the multiframe and frame on the slave link shall occur 3 timeslot durations after the start of the corresponding multiframe and frame on the master link.

For a DM-REP/GATE, the start of the multiframe and frame on the slave link shall occur 3 timeslot durations after the start of the corresponding multiframe and frame on the master link The difference between Ud and Um frame timing varies according to whether repeater functionality is combined with the gateway. For details see EN 300 396-5 [5], clause 13.4.1.

9.4 Physical channels

9.4.1 General

During a call for a DM-MS, a DM physical channel is defined as one radio frequency carrier and two timeslots per frame.

For a type 1A DM-REP, a DM physical channel is defined as a single RF carrier. For a type 1B DM-REP, a DM physical channel is defined as a pair of duplex-spaced RF carriers (f_1 as the "uplink" with f_2 as the associated "downlink"). Two timeslots per frame are used primarily for the master link and the other two timeslots per frame are used primarily for the slave link.

For a DM-GATE or a type 1A DM-REP/GATE, a DM physical channel is defined as a single RF carrier. For a type 1B DM-REP/GATE, a DM physical channel is defined as a pair of duplex-spaced RF carriers (f_1 as the "uplink" with f_2 as the associated "downlink").

9.4.2 Bursts

9.4.2.1 General

A burst is a period of RF carrier that is modulated by a data stream. A burst therefore represents the physical content of a timeslot.

9.4.2.2 Modulation symbol numbering

A timeslot shall be divided into 255 modulation symbol durations, each one with a duration of 1/18 ms (approximately 55,56 µs). A particular modulation symbol within a burst shall be referenced by a Symbol Number (SN), with the first modulation symbol numbered SN1 and the last modulation symbol numbered Snmax.

Different types of bursts are defined, having different durations.

At the beginning of the transmission of a single burst or of consecutive bursts, a supplementary symbol SN0 is defined. It does not carry information but shall be used as phase reference for the differential modulation.

9.4.2.3 Modulation bit numbering

In the following clauses the content of a burst is defined in terms of modulation bits.

A particular modulation bit within a burst shall be referenced by a Bit Number (BN), with the first modulation bit numbered BN1 and the last modulation bit numbered Bnmax. At the modulator the modulation bits shall be grouped in pairs of consecutive odd and even numbered bits and each pair shall be converted into one modulation symbol as described in clause 5.

9.4.2.4 Burst timing

The timing of a modulation symbol is determined by its symbol time. The symbol time is defined as the instant at which the transmitted symbol waveform is at a maximum for the symbol of interest.

The bits BN(2n-1) and BN(2n) shall determine the symbol SN(n) and the symbol time of the modulation symbol SN(n) shall be delayed by (n + d) modulation symbol durations with respect to the start of the slot, with:

- n: integer (1 … (Snmax));
- d: is defined as the burst delay. The burst delay represents the delay between the start of the timeslot and the symbol time of the symbol SN0. The burst delay shall be expressed in modulation symbol duration and varies with the type of burst. The values of the burst delays are given in table 14.

NOTE: Symbol time of the symbol SN0 is same as symbol time of the symbol SN255 of the previous slot.

The symbol time of the symbol SN0 occurs one modulation symbol duration before the symbol time of the symbol SN1 of the first burst of a transmission.

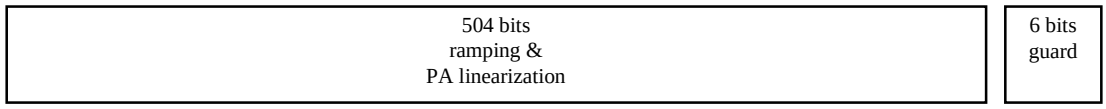
9.4.3 Type of bursts

9.4.3.1 General

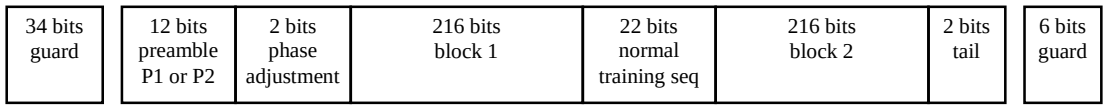
A DM-MS may transmit three types of bursts. The bursts shall conform to the specification in table 14. Figure 12 summarizes the description of the bursts and their timing with respect to the timeslot.

Table 14: Burst types for DM

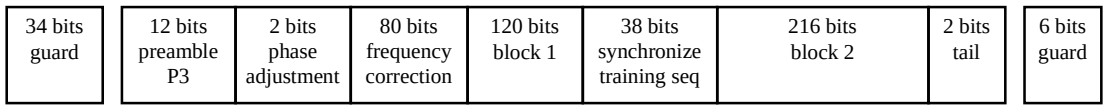
Burst type	Snmax	d burst delay (in symbol duration)	Bit allocation
DMO Linearization burst	N/A	252	clause 9.4.3.2.2
DMO Normal burst	235	17	clause 9.4.3.2.1
DMO Synchronization burst	235	17	clause 9.4.3.2.3



Direct Mode Linearization Burst



Direct Mode Normal Burst



Direct Mode Synchronization Burst

Figure 12: Types of DMO burst

NOTE: The RF Output power time mask is defined in figure 7 and table 6. The t1 period defined in table 6 may be used for ramping and PA linearization.

9.4.3.2 Modulation bits allocation

The bursts are divided into burst fields containing contiguous modulation bits of the same type. The burst fields are described in clause 9.4.3.3.

The DM normal and synchronization bursts contain two independent blocks, called Block 1 (BKN1) and Block 2 (BKN2). A separate logical channel may be mapped on each block. Block 1 and block 2 shall be made of one field and shall contain 216 scrambled bits each in a DM normal burst and 120 and 216 scrambled bits respectively in a DM synchronization burst.

9.4.3.2.1 DM Normal Burst (DNB)

The allocation of the modulation bits in the DNB shall be in accordance with table 15. The DNB shall be used by MSs once synchronization has been achieved to transmit control or traffic messages to other MSs.

Table 15: DNB

Bit Number (BN)	Field length (bits)	Field content	Field bits number	Definition clause or clause
1 to 12	12	preamble	j1 to j12 or k1 to k12	9.4.3.3.3
13 to 14	2	phase adjustment bits	hk1 to hk2	9.4.3.3.5
15 to 230	216	scrambled block 1 bits	bkn1(1) to bkn1(216)	8
231 to 252	22	normal training sequence	n1 to n22 or p1 to p22	9.4.3.3.3
253 to 468	216	scrambled block 2 bits	bkn2(1) to bkn2(216)	8
469 to 470	2	tail bits	t1 to t2	9.4.3.3.6

9.4.3.2.2 DM Linearization Burst (DLB)

The DLB may be used by MSs to linearize their transmitters. The linearization burst contains no useful bits and its timing shall only be determined by the time mask (see clause 6).

9.4.3.2.3 DM Synchronization Burst (DSB)

The allocation of the modulation bits in the DSB shall be in accordance with table 16. DSB shall be for synchronization of MSs participating in a DM communication.

Table 16: DSB

Bit Number (BN)	Field length (bits)	Field content	Field bits number	Definition clause or clause
1 to 12	12	preamble	l1 to l12	9.4.3.3.4
13 to 14	2	phase adjustment bits	hl1 to hl2	9.4.3.3.5
15 to 94	80	frequency correction	f1 to f80	9.4.3.3.1
95 to 214	120	scrambled synchronization block 1 bits	sb(1) to sb(120)	8
215 to 252	38	synchronization training sequence	y1 to y38	9.4.3.3.4
253 to 468	216	scrambled block 2 bits	bkn2(1) to bkn2(216)	8
469 to 470	2	tail bits	t1 to t2	9.4.3.3.6

9.4.3.3 Burst fields

9.4.3.3.1 Frequency correction field

The frequency correction field shall contain 80 bits:

$$(f1, f2, ..., f8) = (1,1,...,1) \quad (55)$$

$$(f9, f10, ..., f72) = (0,0,...,0) \quad (56)$$

$$(f73, f74, ..., f80) = (1,1,...,1) \quad (57)$$

When transmitted, this frequency correction field generates an un-modulated carrier at 2,25 kHz above the carrier frequency, preceded and followed by a short period (4 symbol durations) of un-modulated carrier at 6,75 kHz below the carrier frequency.

9.4.3.3.2 Inter-slot frequency correction field

The DM-MS interslot frequency correction bits are defined as:

$$(g1, g2, ..., g6) = (0,0,...,0) \quad (58)$$

$$(g7, g8, ..., g32) = (1,1,...,1) \quad (59)$$

$$(g33, g34, ..., g40) = (0,0,...,0) \quad (60)$$

When transmitted, this frequency correction field generates an un-modulated carrier at 6,75 kHz below the nominal carrier frequency, preceded and followed by short periods of un-modulated carrier at 2,25 kHz above the nominal carrier frequency.

9.4.3.3.3 Normal training sequence and preamble

Two 22 bit normal training sequences and two 12 bit preambles are defined.

The normal training sequences and preambles shall be used on the DNB. The type of training sequence and preamble shall be used as a flag indicating the presence of one or two logical channels on the blocks 1 and 2 of the burst, according to table 17.

Table 17: Preambles and Training sequences

Preamble	Normal training sequence	Logical channel
P1	1	TCH, SCH/F
P2	2	STCH + TCH, STCH + STCH

The preamble P1 shall be:

$$(j1, j2, ..., j12) = \quad (0,0,\ 1,1,\ 0,0,\ 1,0,\ 0,0,\ 1,1) \tag{61}$$

The preamble P2 shall be:

$$(k1, k2, ..., k12) = \quad (1,0,\ 0,1,\ 1,0,\ 1,0,\ 1,0,\ 0,1) \tag{62}$$

The normal training sequence 1 shall be:

$$(n1, n2, ..., n22) = \quad (1,1,\ 0,1,\ 0,0,\ 0,0,\ 1,1,\ 1,0,\ 1,0,\ 0,1,\ 1,1,\ 0,1,\ 0,0) \tag{63}$$

The normal training sequence 2 shall be:

$$(p1, p2, ..., p22) = \quad (0,1,\ 1,1,\ 1,0,\ 1,0,\ 0,1,\ 0,0,\ 0,0,\ 1,1,\ 0,1,\ 1,1,\ 1,0) \tag{64}$$

9.4.3.3.4 Synchronization training sequence

The synchronization training sequence and 12 bit preamble shall be used on the DSB.

The synchronization preamble P3 shall be:

$$(I1, I2, ..., I12) = \quad (0,0,\ 0,1,\ 0,1,\ 0,0,\ 0,1,\ 1,1) \tag{65}$$

The synchronization training sequence shall be a 38 bit synchronization word used for the synchronization burst.

The synchronization training sequence shall be:

$$(y1, y2, ..., y38) = \quad (1,1,\ 0,0,\ 0,0,\ 0,1,\ 1,0,\ 0,1,\ 1,1,\ 0,0,\ 1,1,\ 1,0,\ 1,0,\ 0,1,\ 1,1,\ 0,0,\ 0,0,\ 0,1,\ 1,0,\ 0,1,\ 1,1) \tag{66}$$

9.4.3.3.5 Phase adjustment bits

The phase adjustment bits shall be used on both the normal and synchronization bursts to provide a known phase relationship between the different preamble sequences and different training sequences of the burst, whatever the content of the blocks is.

The value of the pair of phase adjustment bits shall be set so that the phase shift Dϕ they generate (see clause 5) is equal to:

$$D\phi = -\sum_{n=n1}^{n2} D\phi(n) \tag{67}$$

where:

Dϕ(n) is the phase transition generated by the bits (BN(2n-1), BN(2n)), n1 and n2 are given by table 18 with respect to the bit numbering of clause 9.4.3.2.

Table 18: Phase adjustment bits

phase adjustment bits	n1	n2
(hk1, hk2)	8	126
(hl1, hl2)	8	126

9.4.3.3.6 Tail bits

The tail bit field shall contain 2 bits.

The contents of the tail bit field shall be:

$$(t1, t2) = (0, 0) \quad (68)$$

9.4.4 DM device multiple slot transmission

The DM device transmitting on more than 1 slot need not ramp down and up between adjacent DM bursts. In the case where the DM device does not perform the ramping, the burst shall be followed by 6 bits (corresponding to the guard period) defined in table 19 and the subsequent burst shall be preceded by 34 bits (corresponding to the ramp up and linearization period), according to table 20.

Table 19: Bits following the present burst

Bit Number (BN)	Field length (bits)	Field content	Field bits number	Definition clause or clause
1 to 6	6	interslot frequency correction bits	g1 to g6	9.4.3.3.2

Table 20: Bits preceding the subsequent burst

Bit number (BN)	Field length (bits)	Field content	Field bits number	Definition clause or clause
1 to 26	26	interslot frequency correction bits	g7 to g32	9.4.3.3.2
27 to 34	8	interslot frequency correction bits	g33 to g40	9.4.3.3.2

9.4.5 General mapping of logical channels

Table 21 defines the mapping of logical channels into physical channel types.

Table 21: Mapping of logical channel into physical channels

Logical channel	Burst type	Block	FN	TN
LCH	DLB	-	3	3
SCH/F	DNB	BKN1 + BKN2	1…17	1
SCH/S	DSB	BKN1	1…18	1…4
SCH/H	DSB	BKN2	1…18	1…4
TCH	DNB	BKN1 + BKN2, BKN2	1…17	1
STCH	DNB	BKN1, BKN2	1…17	1

10 Radio subsystem link control

10.1 Introduction

Clause 10 specifies the radio subsystem link control implementation for TETRA DM. The following aspects of radio subsystem link control are addressed:

- RF power control;
- the basis for signal strength measurement.

10.2 RF power control

In direct DM-MS to DM-MS operation a master MS shall always transmit at its nominal power according to clauses 6.4.1 and 6.4.2.

NOTE 1: Under certain operational circumstances a slave MS may reduce its TX power, e.g. if it determines that it is in close proximity to the current master MS. This power reduction mechanism is outside the scope of the present document.

A DM-REP shall always transmit at its nominal power according to clauses 6.4.1 and 6.4.2.

NOTE 2: Adaptive DM-MS RF power control is optional for operation through a type 1 DM-REP for both master and slave DM-MSs. The power reduction mechanism is outside the scope of the present document.

A DM-GATE shall always transmit at its nominal power, as defined in clauses 6.4.1 and 6.4.2, unless it is configured to support only a single DM-MS in which case it is not precluded from implementing power control procedures.

NOTE 3: Adaptive DM-MS RF power control is optional for operation through a gateway for both master and slave DM-MSs, except for the master DM-MS in a group call through a DM-GATE. Adaptive DM-MS RF power control may be implemented as a manufacturer dependent option using similar principles to those defined for open loop power control in TMO operation EN 300 392-2 [2], clause 23.4.4.

10.3 Radio link measurements

The radio link measurements may include signal strength or signal quality.

10.3.1 Signal strength

The received signal strength shall be measured over the range from -115 dBm to -50 dBm, with an absolute accuracy of ±4 dB.

10.3.2 Signal quality

The quality of the radio link shall be estimated from the success rate of decoding the SCH/S (see EN 300 396-3 [3]).

Annex A (informative): Bibliography

ETSI EN 300 396-4: "Terrestrial Trunked Radio (TETRA); Technical requirements for Direct Mode Operation (DMO); Part 4: Type 1 repeater air interface".

ETSI EN 300 396-1: "Terrestrial Trunked Radio (TETRA); Technical requirements for Direct Mode Operation (DMO); Part 1: General network design".

Annex B (informative): Change requests

The present document contains change requests as described in the following table.

No	CR vers.	Standard Version	TS	EN	Clauses affected	Title
002	03	1.2.1		X	Foreword, 2, 3.1, 3.2, 4.8, 6.2, 6.5.3.1, 7.1, 9.3.1, 10.3.2	Editorial changes of references, definitions, abbreviations and related text
003	AWG	1.3.1		X	2, 3.1, 6.1, 7.2, 7.3.2, 7.5	Synchronisation of idle DM-MS
004	05	1.3.1		X	1, 2, 2.1, 2.2, 3.1, 3.2, 3.3, 4.8, 4.9, 6.1, 6.2, 6.3, 6.4.2, 6.4.3.2.1, 6.4.3.2.1, 6.4.3.2.2, 6.4.3.3.1, 6.4.3.3.2, 6.4.5, 6.4.6, 6.4.7, 6.4.7.2, 6.4.7.3, 6.5.3.1, 6.6.2.2, 6.6.2.3, 6.6.2.4, 6.6.2.5, 7.1, 7.2, 7.2.1, 7.2.2, 7.2.3, 7.2.4, 7.2.5, 7.3.1, 7.3.2, 7.4, 7.5, 7.6, 7.7, 7.8, 8.1, 8.3.2, 8.3.2.5, 9.3.1, 9.3.4, 9.4.1, 9.4.4, 10.2, 10.3.2	All radio aspects moved from part 4 and part 5 to part 2

History

Document history		
Edition 1	March 1998	Publication as ETS 300 396-2 (Historical)
V1.2.1	July 2002	Publication
V1.3.1	September 2006	Publication
V1.4.0	August 2011	One-step Approval Procedure OAP 20111222: 2011-08-24 to 2011-12-22