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

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

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Foreword

This European Standard (Telecommunications series) has been produced by ETSI Project Terrestrial Trunked Radio (TETRA).

The present document is part 2 of a multi-part deliverable covering the Terrestrial Trunked Radio (TETRA); 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";

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

Part 9: "Service and Description Language (SDL) model";

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

National transposition dates	
Date of adoption of this EN:	19 July 2002
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1 Scope

EN 300 396 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 - Mobile Station (MS - MS) 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

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

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

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

[2] ETSI ETS 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".

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

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions 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 during a call

NOTE: A call is made up of one or more call transactions. In a simplex call these call transactions are sequential.

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 V+D network

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

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 can have one of two status levels:

- **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 and hence is **deriving** synchronization information from the channel.

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.

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: generic term for 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

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

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

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 EN 300 396-2

3.2 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-MS	Direct Mode Mobile Station
DMO	Direct Mode Operation
DNB	Direct mode Normal Burst
DQPSK	Differential Quaternary Phase Shift Keying
DSB	Direct mode Synchronization Burst

FN	Frame Number
LCH	Linearization CHannel
MER	Message Erasure Rate
mod	modulo (base for counting)
MS	Mobile Station
PACQ	Probability of synchronization burst ACQuisition
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
STCH	STealing CHannel
TCH	Traffic CHannel
TN	Timeslot Number
V+D	Voice plus Data

4 Radio aspects

4.1 Introduction

This clause 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.

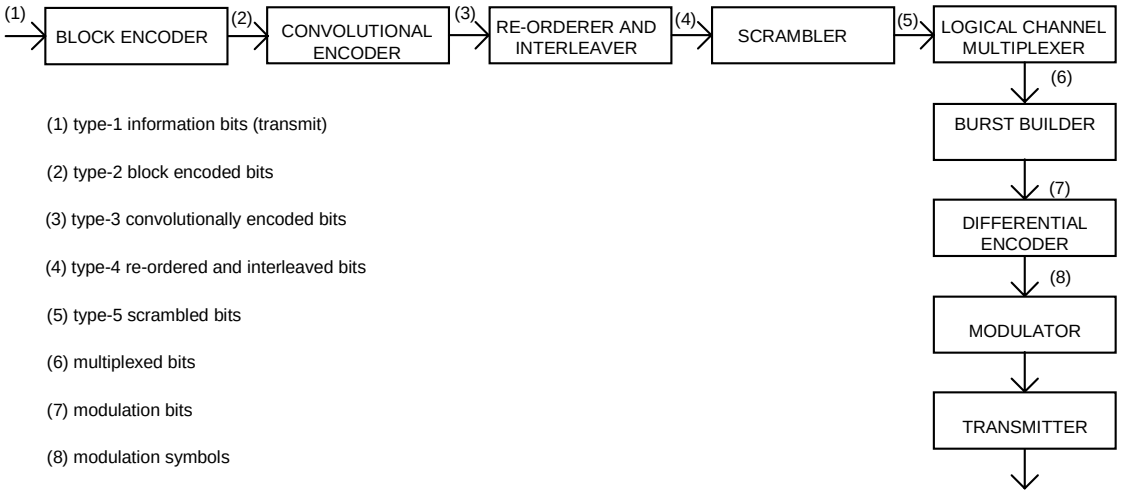

Figure 1: Reference configuration

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.

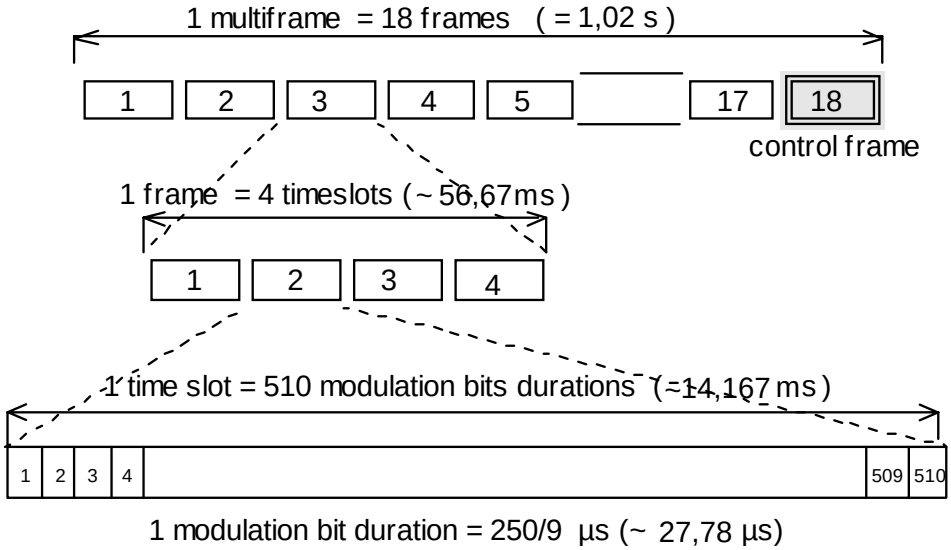

Figure 2: DM framing structure

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 contents 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 channels, together with the requirements on the transmitter and the receiver characteristics are specified in clause 6.

DM-MS 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-MS.

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

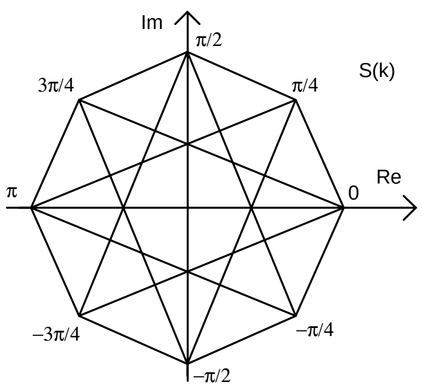

Figure 3: Modulation symbol constellation and possible transitions

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:

$$G(f) = 1 \quad \text{for} \quad |f| \le (1-\alpha)/2T$$

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

$$G(f) = 0 \quad \text{for} \quad |f| \ge (1+\alpha)/2T \quad (4)$$

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).