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Terrestrial Trunked Radio (TETRA); Voice plus Data (V+D); Designers' guide; Part 2: Radio channels, network protocols and service performance

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Foreword

This ETSI Technical Report (ETR) has been produced by the TErrestrial Trunked RAdio (TETRA) ETSI Project of the European Telecommunications Standards Institute (ETSI).

ETRs are informative documents resulting from ETSI studies which are not appropriate for European Telecommunication Standard (ETS) or Interim European Telecommunication Standard (I-ETS) status. An ETR may be used to publish material which is either of an informative nature, relating to the use or the application of ETSs or I-ETSs, or which is immature and not yet suitable for formal adoption as an ETS or an I-ETS.

This ETR consists of 4 parts as follows:

Part 1: "Overview, technical description and radio aspects";

Part 2: "Radio channels, network protocols and service performance";

Part 3: "Direct Mode Operation (DMO)", (DTR/TETRA-01011-3);

Part 4: "Network management".

Annex A provides details of the traffic scenarios for TETRA V+D systems.

Annex B provides Message Sequence Charts (MSCs) of all the simulated procedures.

Annexes C, D and E provide Service Diagrams (SDs) related to the various models. As these diagrams are difficult to read for each diagram a computer file name is provided of the attached electronic files to this ETR. The diagrams provided in this way allows the reader to use suitable software to browse the computer files.

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A number of major contributions have been made by ETSI members in order for this ETR to be comprehensive, and in order that scenario implementations are validated. EPTETRA wishes to acknowledge the work of these contributions from:

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- AEG Mobile Communications Gmbh, Ulm, (D);
- ASCOM TECH. AG, Maegenwil, (CH);
- CSELT S.p.A., Torino, (IT);
- Telecom Consultant International Ltd., (UK);
- TELEDENMARK, Taastrup, (DK); and
- The UK Home Office, London (UK).

Introduction

The design of a mobile radio network is a complex process where many parameters play an important role.

The starting point of this process is the estimate of the traffic that is offered to the network. For a single mobile subscriber, the type of required services, the frequency of requests, the duration and the minimum performance are the common variables that are considered in the estimate. Moreover the number of subscribers and their distribution inside the network allow the estimation of the total amount of traffic.

A parallel operation is the investigation of the propagation environment in the region where the network will be placed.

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The cell positioning and dimensioning is a crucial step in the design process. More than the amount of the offered traffic and of the propagation environment, an important role is played by the knowledge of how the design choices affect the performance for the offered services. This information is strongly related to the particular radio interface of the mobile radio system.

The positioning and dimensioning of network switches and databases close the overall process. As in the case of radio interface, this operation requires the knowledge about the influence of the design choices on the overall performance.

The design process is usually iterative. A final analysis on the whole network allows to check the validity of the process. In case of inadequate result, the process is repeated.

The evaluation of effects of the design choices on the overall network performance is usually performed by simulation (nevertheless, when some network have been deployed, it can be done also through real experiment).

This evaluation should allow the designer to determine the radio coverage and the resource allocation just starting from the target performance for the provided services. Due to the complex structure of a mobile network this operation is usually made by iterations. Starting from the network configuration, the overall performance are evaluated, then the comparison with the target performance can lead to accept or to repeat the evaluation with different parameters.

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1 Scope

The scope of this ETSI Technical Report (ETR) is to be a useful, but not exhaustive, basis to a network designer for the cell planning and radio resource allocation during the design process. This ETR reports the performance of a TErrestrial Trunked RAdio (TETRA) Voice plus Data (V+D) network in some different scenarios.

All the presented results have been evaluated through computer simulations by some companies taking part in the TETRA standardization bodies. The network users involved in the development of the TETRA standard provided some realistic and significant network scenarios, giving information about the offered traffic.

The characterization of radio channels is the first step for the evaluation of performance of both network protocols and quality of provided services. This ETR starts with the description and the illustration of performance of TETRA V+D radio channels, in terms of Bit Error Ratio (BER) and Message Erasure Rate (MER) as function of the Signal-to-Noise Ratio (SNR) and Carrier on co-channel Interference ratio (C/I).

This ETR also deals with the performance of network protocols (in terms of delay and throughput) and of provided services (BER for circuit switched services and delay plus throughput for packet switched services). A consequence of the analysis of access protocols is the evaluation of traffic capacity of control and traffic channels.

2 References

For the purposes of this ETR, the following references apply.

[1] ETS 300 392-1: "Radio Equipment and Systems (RES); Trans-European Trunked Radio (TETRA) system; Voice plus Data; Part 1: General network design".

[2] ETS 300 392-2: "Radio Equipment and Systems (RES); Trans-European Trunked Radio (TETRA) system; Voice plus Data; Part 2: Air Interface".

[3] CEC Report COST 207: "Digital Land Mobile Communications".

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3 Abbreviations

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

AACH	Access Assign CHannel
BER	Bit Error Rate
BNCH	Broadcast Network CHannel
BSCH	Broadcast Synchronization CHannel
BUx	Bad Urban at x km/h
C/I_c	Carrier on co-channel Interference ratio
CC	Call Control
CONP	Connection Oriented Network Protocol
E_s/N_0	Signal on Noise ratio
HH	Hand Held
HTx	Hilly Terrain at x km/h
LLC	Logical Link Control
MAC	Medium Access Control
MCCH	Main Control CHannel
MER	Message Erasure Rate
MLE	Mobile Link Entity
MS	Mobile Station
MSC	Message Sequence Chart
MT	Mobile Terminal
PAMR	Public Access Mobile Radio
PDO	Packet Data Optimized
PDU	Protocol Data Unit
PMR	Private Mobile Radio

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PUEM	Probability of Undetected Erroneous Messages
RAx	Rural Area at x km/h
RES	Radio Equipment and Systems
SCH / F	Signalling CHannel / Full slot
SCH / HD	Signalling CHannel / Half slot Downlink
SCH / HU	Signalling CHannel / Half slot Uplink
SCLNP	Special Connection Less Network Protocol
SDL	Specification and Description Language
SDU	Service Data Unit
SwMI	Switching and Mobility Infrastructure
TCH/x N=y	Traffic CHannel for x kbit/s and interleaving depth N=y
TCH// S	Traffic CHannel / Speech
TDMA	Time Division Multiple Access
TETRA	TErrestrial Trunked RAdio
TUx	Typical Urban at x km/h
V+D	Voice plus Data

4 Radio channels performance

4.1 Introduction

Performance of TETRA V+D logical radio channels are reported in this clause. They have been evaluated through computer simulations for all the propagation environments that are modelled in ETS 300 392-2 [2], clause 6. Moreover, performance are also reported for some values of the Mobile Station (MS) speed in each propagation environment.

Radio channel figures are preceded by the description of the model of radio channels and of the assumptions that have been considered for simulations. Then, for each channel, performance figures are grouped and showed in the following order:

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- comparison among different propagation environments with one value of MS speed per environment;

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- performance sensitivity to the MS speed in TU propagation environment;
- performance sensitivity to the MS speed in BU propagation environment;
- performance sensitivity to the MS speed in RA propagation environment;
- performance sensitivity to the MS speed in HT propagation environment.

Due to the different possibilities in the model of the radio receiver, two groups of simulations have been carried out:

1) the first with ideal synchronization technique; and

2) the second with a particular implementation of the synchronization block.

In this ETR performance figures are distinguished in two subclauses for each channel and scenario.

Figures that are reported in this clause will be considered as the basis for the evaluation of network protocol and traffic performance, presented in the following clauses.

4.2 Radio channels simulation description

Each of the TETRA V+D logical channels has been defined in order to exploit particular data transmissions (protocol messages or user data) over the radio interface. In order to match the requirements related to throughput and error rate, each channel has been designed with a suitable coding scheme. The complete description of logical channels is found in ETS 300 392-2 [2], clause 8.

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On the basis of their usage in the system, the logical channels can be divided in two main groups:

- Signalling channels:

  All signalling messages and packet switched user data are carried on these channels. Error detection and error correction coding schemes are applied on transmitted messages. Moreover for these applications it is required that corrupted messages are discarded in order to not cause erroneous state transitions. The coding schemes of TETRA V+D channels have been designed in order to minimize the probability that an erroneous message is not detected (PUEM). According to ETS 300 392-2 [2], PUEM < 0,001 % is obtained for all signalling channels with the exception of AACH (PUEM < 0,01 %). Due to the usage of these channels, the measured performance is the MER.

- Traffic channels:

  Speech frames and circuit switched user data are carried on traffic channels. Error detection and error correction coding schemes are applied on transmitted data. No discarding mechanism is performed on traffic channels with the exception of the TCH/S. Before entering the speech decoder, the speech frame is discarded if corrupted. For all the other traffic channels received data are presented to the user application even if corrupted. In general, it is significant that the measured performance for traffic channels is the BER. Due to the particular design of the TCH/S channel, its performance is measured in terms of both MER and residual BER (that is the BER detected on speech frames that are not discarded).

Table 1 summarizes the main characteristics of TETRA V+D logical channels and indicates the evaluated performance.

Table 1: Summary of logical channels characteristics.

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Logical Channel	Direction	Physical resource	Category	Evaluated performance
AACH	Downlink	30 initial bits of downlink timeslot	Signalling	MER
SCH/HD, BNCH and STCH	Downlink	Half slot	Signalling	MER
SCH/HU	Uplink	Half slot	Signalling	MER
BSCH	Downlink	Full slot	Signalling	MER
SCH/F	Uplink / Downlink	Full slot	Signalling	MER
TCH/S	Uplink / Downlink	Full slot	Traffic (Speech)	MER, residual BER
TCH/7,2	Uplink / Downlink	Full slot	Traffic (Data)	BER
TCH/4,8 (N=1, 4, 8)	Uplink / Downlink	Full slot	Traffic (Data)	BER
TCH/2,4 (N=1, 4, 8)	Uplink / Downlink	Full slot	Traffic (Data)	BER

A further element of distinction is the transmission mode of a channel: uplink, discontinuous downlink and continuous downlink. Traffic channels and the SCH/F allow all these modes. The difference is the type and the number of training sequences inserted in the transmitted radio bursts.

Radio receiver simulations have been performed according to the model represented in figure 1.

The transmitter has been modelled according to the standard scheme given in ETS 300 392-2 [2], clause 4.

The structure of the radio receiver is not covered by the standard. The model given in figure 1 is a general scheme that is commonly accepted. Some of the receiver blocks are the mirror counterpart of others on the transmitter (root raised cosine filter, demodulator, differential decoder, burst splitter, de-scrambler and de-interleaver). Nevertheless the structure of the other blocks is dependent from the implementation; it is the case for synchronization and timing recovery block and for the decoder.

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The decoder block has been realized according to the “soft” decision Viterbi algorithm, with path length = message length.

The synchronization and timing recovery block can be realized according to different schemes. For this reason simulations have been performed according to the two following synchronization techniques:

- ideal technique:
    - the local timing system of the receiver is perfectly aligned to the received TDMA frames;
- realistic implementation of the synchronization technique:
    - one realization of synchronization technique has been implemented; this technique exploits correlation properties of the training sequences defined in the standard in order to evaluate burst and symbol synchronization.

The physical radio channels have been modelled according to ETS 300 392-2 [2], clause 6.

At the top of figure 1 two blocks have been introduced in order to evaluate the radio channel characteristics.

In the case of signalling channels and TCH/S simulations, accepted and discarded Medium Access Control (MAC) blocks are counted. The evaluated MER is given by the ratio between discarded MAC blocks and the total of transmitted blocks.

In the case of traffic channels a comparison between transmitted and correspondent received bits allows the evaluation of the total amount of erroneous received bits. The evaluated BER is given by the ratio between the number of erroneous bits and the total number of transmitted bits.

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The number of training sequences that is transmitted inside radio bursts may influence the behaviour of the synchronization and timing recovery block, depending on its particular implementation. In the case of ideal synchronization technique there is no influence. In the case of realistic synchronization algorithms implementations without equalizer, the impact of the number of training sequences on radio performance is negligible if compared to the case of receiver with equalizer.

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The radio receiver that has been simulated does not make use of equalizers. As a consequence, in the case of traffic channels and SCH/F, performance related to uplink, discontinuous downlink and continuous downlink transmission modes will be considered without distinction.

Radio channel performance have been evaluated as functions of E_s/N_0 or C/I_c at the antenna connector of the receiver. E_s is the energy associated to a modulation symbol, N_0 (one-sided noise power spectral density) is the energy of electric noise related to the modulation symbol period and due to other phenomena than TETRA transmissions; in actual simulations it will be only related to thermal noise; C is the transmitted power associated to the modulation symbol; I_c is the power associated to a pseudo-random continuous TETRA modulated signal that takes place on the same frequency (co-channel interference) of the useful signal. The figures of the channels show that the influence of E_s/N_0 on channel performance is similar to the influence of C/I_c. Differences between curves are less than 1 dB for the same performance level.

Due to the differences in the synchronization technique, two groups of results are presented for each logical channel. Performance of each synchronization technique is evaluated for different propagation scenarios (TU, BU, RA, HT) and considering different values of the mobile terminal speed.

The two groups of results in this ETR have to be considered as a sort of performance boundaries. For each simulation scenario real receivers are reasonably expected to have performance within the range limited by the evaluated curves for the two synchronization techniques.

Results of simulations obtained from different companies show a good agreement. Radio channel performance in this ETR have been evaluated as an average of available homogeneous simulation results from different companies.

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Making reference to figure 1, and according to the previous assumptions, simulations have been performed according to the following assumptions:

- ideal transmitter:
  - all blocks in the transmitter have an ideal behaviour as described in ETS 300 392-2 [2];
- ideal RF receiver:
  - the RF to baseband signal conversion is considered ideal;
- 400 MHz carrier frequency;
- analysis of performance versus E_s/N_0 and C/I_c;
- class B receiver:
  - radio channel simulations in this clause are performed to meet class B receiver requirements as defined in ETS 300 392-2 [2]:
    - better performance is expected to be given by a receiver with an equalizer block;
- 10 000 MAC blocks per simulation point:
  - each simulated point has been evaluated on a set of 10000 MAC blocks;
- ideal and realistic synchronization technique:
  - when available two groups of performance are reported for each logical channel, one for ideal synchronization technique, the other for realistic technique;
- soft decision Viterbi decoder with path length = message length.

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