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Part 2: Radio channels, network protocols and service performance

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ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° 7803/88

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Contents

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Terrestrial Trunked Radio (TETRA).

The present document is part 6 of a multi-part deliverable covering Terrestrial Trunked Radio (TETRA); Voice plus Data (V+D); Designers' guide, as identified below:

ETR 300-1: "Overview, technical description and radio aspects";

TR 102 300-2: "Radio channels, network protocols and service performance";

TR 102 300-3: "Direct Mode Operation (DMO)";

ETR 300-4: "Network management";

TR 102 300-5: "Guidance on numbering and addressing";

TR 102 300-6: "Air-Ground-Air".

This version of the present document adds results of the new simulations done in setting performance requirements for TETRA equipment working at frequency range 138 MHz to 300 MHz.

The original document (ETR 300-2 ed.1) is kept without modifications and the new result as presented in annexes F and G.

NOTE: Clauses 4 to 5.6.5 and annexes A to E contain historical information and that may have been modified in the actual protocol definitions in EN 300 392-2 [i.2].

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.

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.

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.

1 Scope

The scope of the present document 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. The present document 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. The present document 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).

The present document 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

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 referenced 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.

Not applicable.

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

[i.2] ETSI EN 300 392-2 / ETSI TS 100 392-2: "Terrestrial Trunked Radio (TETRA); Voice plus Data (V+D); Part 2: Air Interface (AI)".

NOTE: The references EN 300 392-2 and TS 100 392-2 are two instances of the same document. For a shorter presentation only EN 300 392-2 [i.2] is used as the reference in the present document.

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

3 Abbreviations

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

AACH	Access Assign CHannel
BER	Bit Error Rate
BNCH	Broadcast Network CHannel
BS	Base Station
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
DMO	Direct Mode Operation
E_s/N_0	Signal on Noise ratio
HTx	Hilly Terrain at x km/h
ISDN	Intergrated Services Digital Network
LLC	Logical Link Control
MAC	Medium Access Control
MCCH	Main Control CHannel
MER	Message Erasure Rate
MLE	Mobile Link Entity
MMI	Man Machine Interface
MS	Mobile Station
MSC	Message Sequence Chart
NFD	Net Filter Discrimination
PAMR	Public Access Mobile Radio
PDU	Protocol Data Unit
PMR	Private Mobile Radio
PSTN	Public Services Telephone Network
PUEM	Probability of Undetected Erroneous Messages
RAx	Rural Area at x km/h
RCPC	Rate Compatible Punctured Convolutional
REF	REFerence
RF	Radio Frequency
RM	Reed-Müller
SCH	Signalling CHannel
SCH/F	Signalling CHannel / Full slot
SCH/F	Signalling CHannel, Full size
SCH/HD	Signalling CHannel / Half slot Downlink
SCH/HD	Signalling CHannel, Half size Downlink
SCH/HU	Signalling CHannel / Half slot Uplink
SCH/HU	Signalling CHannel, Half size Uplink
SCLNP	Special Connection Less Network Protocol
SDL	Specification and Description Language
SDS	Short Data Service
SNR	Signal to Noise Ratio
STCH	STealing CHannel
SwMI	Switching and Mobility Infrastructure
TCH	Traffic CHannel
TCH/S	Traffic CHannel / Speech
TCH/x N=y	Traffic CHannel for x kbit/s and interleaving depth N=y
TDMA	Time Division Multiple Access
TETRA	TErrestrial Trunked RAdio
trasm/h	Transmissions per hour
TUx	Typical Urban at x km/h
UNIF	UNIForm
V+D	Voice plus Data
π/4-DQPSK	π/4-shifted Differential Quaternary Phase Shift Keying

NOTE: Instead of HTx and Tux also HT-x and TU-x are used in the present document.

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 EN 300 392-2 [i.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:

- comparison among different propagation environments with one value of MS speed per environment;
- 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 the present document performance figures are distinguished in two clauses 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 EN 300 392-2 [i.2], clause 8.

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 EN 300 392-2 [i.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.

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 EN 300 392-2 [i.2], clause 4.3.

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.

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 EN 300 392-2 [i.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.

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.

The radio receiver that has been simulated does not make use of equalisers. 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.

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 EN 300 392-2 [i.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 EN 300 392-2 [i.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 10 000 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.