ETSI TR 103 053 V1.1.1 (2014-09)

Fixed Radio Systems;
Parameters affecting the Signal-to-Noise Ratio (SNR) and the Receiver Signal Level (RSL) threshold in point-to-point receivers;
Theory and practice

Reference
DTR/ATTM-04015

Keywords
noise, point-to-point, receiver

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Contents

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Access, Terminals, Transmission and Multiplexing (ATTM).

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**may not**", "**need**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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Introduction

Digital Fixed Radio Systems (DFRS) had been historically specified in a relatively large number of specific European Norms produced by ETSI. These ENs were prepared separately and, even if the list of standardized parameters was common to all these ENs, their specific values were defined on a case-by-case basis. The content of the old Point-to-Point ENs was further transferred into the multipart standard EN 302 217 [i.4] while in a first time most of the parameters values were kept unchanged.

As a consequence the RSL figures provided in earlier versions up to V1.4.1 of EN 302 217-2-2 [i.2] are an array of values proposed at different times and corresponding to different technology situations.

1 Scope

The present document provides guidance for the definition of a full set of rationalized RSL values based on the most recent technological state-of-the-art and determined using a common set of rules for all P-P systems within the scope of EN 302 217 [i.4].

As part of the rationalization effort of EN 302 217 [i.4], the present document proposes technical parameters to be used as basis in the calculation of the RSL figures.

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.

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 302 217-1: "Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas; Part 1: Overview and system-independent common characteristics".

[i.2] ETSI EN 302 217-2-2: "Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas; Part 2-2: Digital systems operating in frequency bands where frequency co-ordination is applied; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive".

[i.3] Directive 1999/5/EC of the European Parliament and of the Council of 9 March 1999 on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity (R&TTE Directive).

[i.4] ETSI EN 302 217 (all parts): "Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas".

[i.5] IEEE 802.16: "IEEE Standard for Air Interface for Broadband Wireless Access Systems".

[i.6] Recommendation ITU-R F.1101: "Characteristics of digital fixed wireless systems below about 17 GHz".

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

air interface interoperability: requirement by which DFRS terminals from different manufacturer can be connected inside the same radio systems

NOTE: It requires standardization of the physical radio layer (e.g. modulation format, digital codings, synchronization procedures, etc.) and part or all of the higher network layers protocols.

digital fixed radio systems: comprise the whole family of Point-to-point (P-P), Point-to-multipoint (P-MP) and Multipoint-to-multipoint (MP-MP) radio equipment (see note 2), which may be used in fixed locations as part of public or private core or access networks (see note 3)

NOTE 1: It is equivalent to the ITU-R definition of Fixed Wireless Systems (FWS) and comprises Fixed Wireless Access (FWA) systems and, in specific cases, their optional extension to Nomadic Wireless Access (NWA).

NOTE 2: The two latter generically identified as Multipoint (MP) systems.

NOTE 3: Analogue systems are no longer implemented; therefore, for the purpose of the present document only digital applications are identified as DFRS.

essential phenomenon: radio frequency phenomenon related to the essential requirements under article 3.2 of the R&TTE Directive [i.3] that is capable of expression in terms of quantifiable technical parameters

harmonized radio frequency band: commonly referred to as a portion of the frequency spectrum that CEPT/ECC (formerly CEPT/ERC) allocates to a specific service through a CEPT/ECC Decision (proper definition is currently under study by CEPT/ERC)

NOTE: It should be noted that, presently, radio frequency bands allocated to Fixed Service are not harmonized.

3.2 Symbols

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

dB	deciBels
GHz	GigaHertz
Hz	Hertz

3.3 Abbreviations

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

AWGN	Additive White Gaussian Noise
BER	Bit Error Ratio
CRL	Carrier Removal Loop
CS	Channel Separation
DEG	Signal Degradation
DFRS	Digital Fixed Radio System
EVM	Error Vector Magnitude
FEC	Forward Error Correction Code
FSK	Frequency Shift Keyed
GF	Galois Field

NOTE: RS code is based on its properties.

IM3	3rd order Inter Modulation
IMD	Inter Modulations Distortion
IPN	Integrated Phase Noise
ITU-R	International Telecommunication Union - Radiocommunications standardization sector

LDPC	Low Density Parity Checking Code
LNA	Low Noise Amplifier
LO	Local Oscillator
MLC	Multi-Level Coding
N_{DEG}	Degraded noise power
NEB	Noise Equivalent Bandwidth
NF	Noise Figure
PLL	Phase Locked Loop
PN	Phase Noise
PSK	Phase Shift Keying
QAM	Quadrature Amplitude Modulation
RF	Radio Frequency
RRC	Root Raised Cosine

NOTE: A common type of channel filter.

RS	Reed-Solomon code

NOTE: A common type of forward error correction code.

RSL	Receiver Signal Level

NOTE: Given at dBm of signal at the antenna port.

RX	Receiver
S_{DEG}	Power of a degraded signal
S_{ND}	Signal power without any source of degradation
SNR	Signal to Noise Ratio
TCM	Trellis Coded Modulation
TX	Transceiver
VCO	Voltage Controlled Oscillator

4 Proposed technical parameters

The RSL (Received Signal Level) is defined for the following BER points:

- RSL for BER $\leq 10^{-6}$
- RSL for BER $\leq 10^{-8}$
- RSL for BER $\leq 10^{-10}$

4.1 Forward error correction code

Modern P-P digital fixed radio systems use Forward Error Correction (FEC) Coding, also called Channel Coding, to improve BER performance.

Many types of FECs are available in today's communication world. These codes, specifically when associated to an iterative decoding process, offer unprecedent coding gain, thus enabling new communication schemes to operate closer and closer to the Shannon bound.

The two main categories of FEC are block codes and convolutional codes. Coded modulation is a particular coding scheme where the coding gain results from an expansion of the number of states of the modulation format for a given spectral efficiency rather than by an increase of the transmitted bitrate.

The following coding schemes are currently implemented:

- Block codes, typically Reed-Solomon (RS) codes.
- Coded modulation: Several coded modulation schemes with very similar performance are described in the literature, especially Multi-level coding (MLC) and Trellis Coded Modulation (TCM).

- A combination of an outer code and an inner code, which provides increased BER performance. This combination generally associates a RS code as outer code and a coded modulation scheme as inner code. The benefit of this association is balanced by the higher latency of the transmission system, due to the need to implement an interleaving matrix between the outer and inner codes.

- Turbo codes and/or Low Density Parity Checking (LDPC) codes which, being using iterative decoding techniques, provide results close to the Shannon limit.

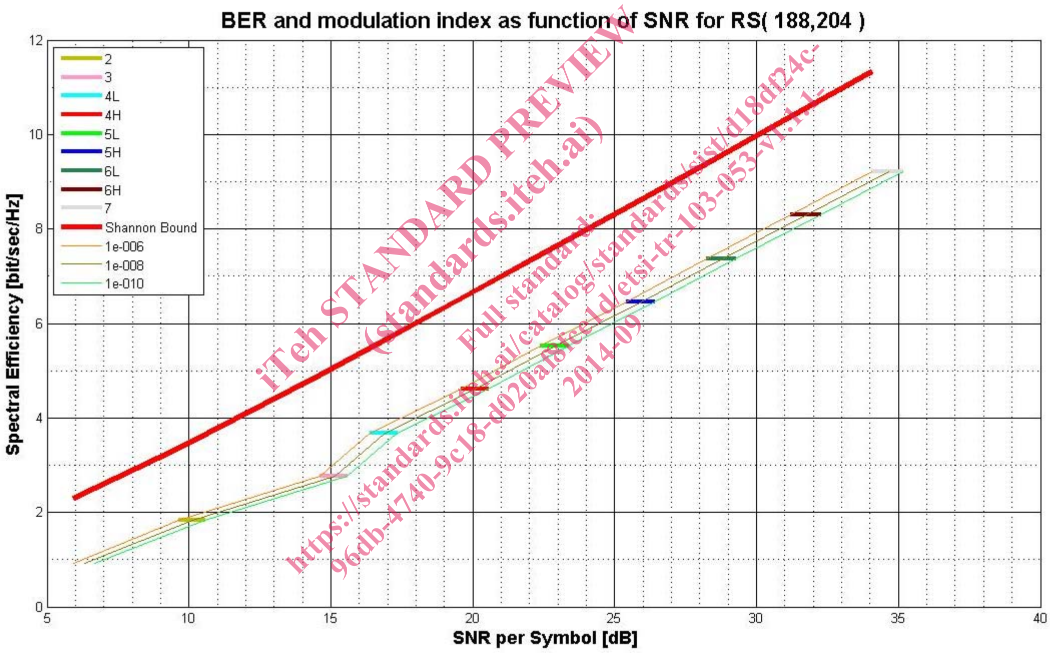
As an example, this clause presents the characteristics in terms of BER of a P-P equipment using two Reed-Solomon codes, RS(204, 188) and RS(200, 190) respectively.

RS(204, 188), which is a Reed-Solomon code over GF(256), has been retained by several standardization bodies. This code has approximately 8 % redundancy and typically corrects up to 8 errored bytes in every block of 204 bytes.

The code RS(204,188) is used in many applications such as DVB-S/T/C, IEEE 802.16 [i.5] and others.

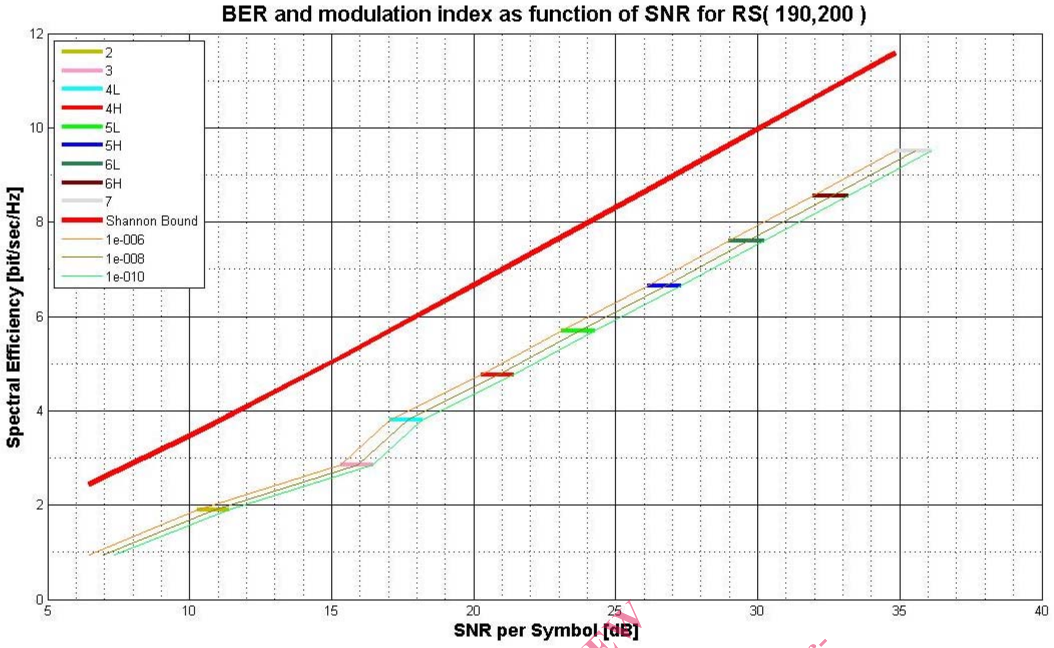
A lower code rate (with approximately 5 % redundancy) is also considered, this code RS(200,190) typically corrects up to 5 errored bytes in every block of 200 bytes.

The performance of RS(204, 188) and RS(200,190) are reported in figure 1 and figure 2 respectively.



NOTE: The spectral efficiency is the "net" one (i.e. divided by 204/188).

Figure 1: BER and modulation index as function of SNR for RS(188,204)



NOTE: The spectral efficiency is the "net" one (i.e. divided by 200/190).

Figure 2: BER and modulation index as function of SNR for RS(190,200)

The Signal-to-Noise Ratio (SNR) for a given BER is a characteristic of the coding and modulation format. The theoretical values of SNR at a BER of 10^{-6} for coded and uncoded systems using modulation formats from 2 PSK to 1 024 QAM are provided in table 1.

Table 1: SNR at BER of 10^{-6} for different modulation and coding formats

Modulation	Uncoded (see note) (dB)	Coded (RS200,190) (dB)	Coded (RS204,188) (dB)
2 PSK	10,5	7,5	6,8
4 QAM	13,5	10,5	9,8
8 PSK	18,8	15,5	14,8
16 QAM	20,5	17,2	16,5
32 QAM	23,5	20,4	19,7
64 QAM	26,5	23,4	22,7
128 QAM	29,5	26,3	25,6
256 QAM	32,5	29,3	28,6
512 QAM	35,5	32,1	31,4
1 024 QAM	38,7	34,8	33,9
NOTE: The values of SNR for uncoded systems from 2 PSK to 512 QAM are taken from Recommendation ITU-R F.1101 [i.6].			

Taking into account the proximity of these results a coding gain of 3 dB for all modulation formats has been assumed in the calculations and will reflect "maximal values" of SNR for modern systems implementing coded modulations.

The theoretical SNR values at lower bit rates could also be determined the same way. With the RS error correction code, the $10^{-6}/10^{-10}$ slope is of 1 dB or less.

Nevertheless, such a slope would not reflect properly actual conditions in digital fixed radio systems:

- Even at high C/IM3 ratio, the amount of degradation of different BER thresholds due to C/IM3 ratio is likely not to be the same at different BERs.
- At very low BER, a number of other implementation factors (e.g. scrambling, mapping, clock imprecision, uncoded bytes, etc.) give significant impact to actual SNR that can hardly be simulated.

Therefore, while simulations for BER 10^{-6}, where the thermal noise is the dominant factor, provide appropriate calculation of the degradation, at lower BER a pragmatic approach has been adopted, using a predefined slope between RSL at a BER of 10^{-6} and RSL at lower BER.

Table 2: Derivation of SNR at BER of 10^{-8} and SNR at BER of 10^{-10}

BER	SNR "maximal"
10^{-6}	3 dB coding gain
10^{-8}	SNR at BER of 10^{-6} + 1,5 dB
10^{-10}	SNR at BER of 10^{-6} + 3 dB

4.2 Noise figure and RX duplexer loss

Noise figure and the RX duplexer losses are obviously contributing to the degradation of the sensitivity of the system; they are necessary parameters for defining the RSL threshold.

In common practice, the "system noise figure" is intended as the overall system noise figure composed by the sum of the noise figure of the receiver chain (evaluated from LNA input to the demodulator input) plus the RX side branching loss (duplexer insertion loss).

For a detailed analysis in view of defining a "reference" value for comparison, these two components should be separately analysed.

Practical low noise amplifiers and associated receiver chains for high frequencies have higher noise figure than practical LNAs for lower frequencies. The variation is assumed to be continuously increasing with the frequency. However, the technology impact (mostly for size problems) for lower bands implies that the front–end noise figure may not drop as low as the single active components would permit.

Similarly, also RX side duplexer are subject to a number of factors affecting their losses (evaluated, according to EN 302 217-1 [i.1], at the reference point B or the reference point C when they are coincident). Examples of such factors are:

- Technology: filters may be realized with many technologies for reducing their size and/or their losses and/or their cost. In particular, the change of technology for size constraint tends to compress the variation of the natural increasing of loss with the frequency.
- Channel arrangement: in a number of bands, different channel arrangements with different TX/RX duplex separations are used in different countries. Even if, in most cases, the difference in losses is not a major issue, this fact should be here mentioned and kept in mind.
- Configuration: according to the user needs, different protection configuration or number of channels may be connected to the same antenna port. This implies that the same equipment may be connected to different types of duplexers (e.g. from the simplest 1+0 configuration, to the 1+1 hot-standby, to the N+1 of trunk applications); also outdoor or full indoor mount implies differences from the duplexer point of view.

For providing a homogeneous guidance and the "total reference noise figure", the duplexer losses are defined according the following assumptions:

a) The technology should not result in inhomogeneous figures. The optimization of cost and performance is a common target; therefore, this should imply that in each band the same technology is likely to be used.

b) For the channel arrangement variants only the lowest duplex separation, implying the expected highest losses in the band, are considered.

c) For the configuration only the simplest 1+0 configuration (generally available for all equipment on the market) are considered (see note).

NOTE: Also in link budget analysis the more complex and lossy configurations are often taken into account as "additional losses" over the 1+0 configuration; therefore, this seems the best choice for a homogeneous definition of "reference values".