ETSI TR 103 554-2 V1.1.1 (2021-02)

Rail Telecommunications (RT); Next Generation Communication System; Radio performance simulations and evaluations in rail environment; Part 2: New Radio (NR)

Reference
DTR/RT-0050

Keywords
FRMCS, radio, railways, simulation

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Railway Telecommunications (RT).

The present document is part 2 of a multi-part deliverable covering radio performance simulations and evaluations in rail environment, as identified below:

Part 1: "Long Term Evolution (LTE)";

Part 2: "New Radio (NR)".

Modal verbs terminology

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Executive summary

In order to assess 3GPP NR radio performance in a rail environment, several scenarios have been defined representing various radio conditions typical to rail environment in the 900 MHz with FDD of 5 MHz bandwidth and the 1 900 - 1 910 MHz band with TDD. Intersite distances between 2 km and 8 km were evaluated in system simulations by 3 companies, noted as Company A, Company B and Company C. The tables in clause 6 summarize the data throughputs simulated by each company in each scenario.

Introduction

3GPP NR radio access is one of the candidates for the radio access technology to be used for the Future Rail Mobile Communications System (FRMCS). In the present document, the term FRMCS refers -unless stated otherwise- to the radio part of the communication system.

Radio performance evaluation of NR system could be done by simulation, through software and processing resources only, or through a test bench incorporating pieces of equipment emulating parts of the chain, e.g. the RF. In both cases, it is important to align the parameters and the assumptions made in the simulation and in the evaluation chain to be able to better reflect a deployment in a rail environment, and to better compare and understand the simulation and the evaluation results.

The present document reports the assumptions and results conducted within TC RT of NR radio performance simulations and evaluations in rail environment.

The purpose of the present document is to summarize the results of the system simulations for a railway environment in both urban and rural scenarios given typical inter-site distances for each scenario. The main bulk of the present document is devoted to the results and analysis of an extensive system simulation campaign that was performed by 3 companies using similar input assumptions but with varying system simulation methodologies.

1 Scope

The present document is intended to:

- Define the simulation parameters relevant to rail environment relating to 3GPP NR radio performance in the 900 MHz (FDD) and 1 900 MHZ (TDD) frequency band. This includes operating frequency bands, bandwidths, deployment scenario (inter-site distance) and antenna characteristics, transmit powers and channel models, along with relevant metrics to be evaluated.
- Collect and analyse the simulation results of an NR system in the rail environment.
- Identify potential limitations of NR system in the rail environment.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative 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.

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

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 TR 103 554-1: "Rail Telecommunications (RT); Next Generation Communication System; LTE radio performance simulations and evaluations in rail environment; Part 1: Long Term Evolution (LTE)".

[i.2] Recommendation ITU-R M.2135-1 (12/2009): "Guidelines for evaluation of radio interface technologies for IMT-Advanced".

[i.3] 3GPP TR 36.873: "Study on 3D channel model for LTE".

[i.4] ETSI TS 138 213: "5G; NR; Physical layer procedures for control (3GPP TS 38.213)".

[i.5] ETSI TR 138 901: "5G; Study on channel model for frequencies from 0.5 to 100 GHz (3GPP TR 38.901)".

[i.6] Kathrein model no. 80010991.

[i.7] ETSI TS 138 214: "5G; NR; Physical layer procedures for data (3GPP TS 38.214)".

[i.8] ETSI TS 138 211: "5G; NR; Physical channels and modulation (3GPP TS 38.211)".

[i.9] 3GPP TR 36.884: "Performance requirements of MMSE-IRC receiver for LTE BS".

[i.10] Recommendation ITU-R F.1336-5: "Reference radiation patterns of omnidirectional, sectoral and other antennas for the fixed and mobile service for use in sharing studies in the frequency range from 400 MHz to about 70 GHz".

[i.11] Erik Dahlman, Stefan Parkvall, Johan Sköld: "5G NR: The Next Generation Wireless Access Technology", Elsevier/Academic Press, 2018.

[i.12] 3GPP TR 36.878: "Study on performance enhancements for high speed scenario in LTE".

[i.13] 3GPP 36.814: "Evolved Universal Terrestrial Radio Access (E-UTRA); Further advancements for E-UTRA physical layer aspects".

3 Definition of terms, symbols and abbreviations

3.1 Terms

Void.

3.2 Symbols

Void.

3.3 Abbreviations

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

3GPP	3rd Generation Partnership Project
5G	Fifth Generation Mobile Networks
AWGN	Additive White Gauss Noise
BLER	BLock Error Rate
BS	Base Station
BTS	Base Transceiver Station
BW	BandWidth
CDF	Cumulative Distribution Function
CDL	Clustered Delay Line
CDL-C	Cluster Delay Line -C Profile
CDM	Code Division Multiplexing
COST	Cooperation of Scientific and Technical
CQI	Channel Quality Information
CSI	Channel State Information
CSI-RS	Channel State Information- Reference Signal
DL	DownLink
DMRS	Demodulation Reference Signal
DM-RS	Demodulation Reference Signal
DS	Delay Spread
EESM	Exponential Effective SNR Mapping
EIRENE	European Integrated Radio Enhanced NEtwork
EIRP	Equivalent Isotropically Radiated Power
EPRE	Emitted Power per Resource Element
FDD	Frequency Division Duplex
FRMCS	Future Rail Mobile Communications System
GSM	Global System for Mobile Communications
HARQ	Hybrid Automatic Repeat Request
HD	High Density
HPBW	Half-Power BeamWidth
INR	Interference-to-Noise Ratio
IRC	Idle Receiver Control
ISD	Inter-Site Distance
KM	Kilometer
KPI	Key Performance Indicator
LDPC	Low Density Parity Check
LOS	Line of Sight
LTE	Long Term Evolution
MCL	Minimum Coupling Loss

MCS	Modulation and Coding scheme
MIMO	Multiple Input Multiple Output
MMSE	Minimum Mean Square Error
MMSE-IRC	Minimum Mean Square Error - Interference Rejection Combining
NLOS	Near Line of Sight
NR	New Radio
NR_X	Number of Receive Antennas
NT_X	Number or Transmit Antennas
OFDM	Orthogonal Frequency Division Multiplexing
PC	Power Control
PDCCH	Physical Downlink Control CHannel
PDSCH	Physical Downlink Shared Channel
PER	Packet Error Rate
PHY	Physical Layer
PRB	Physical Resource Block
PTRS	Phase Tracking Reference Signal
PUCCH	Physical Uplink Control CHannel
PUSCH	Physical Uplink Shared Channel
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RB	Resource Block
RF	Radio Frequency
RHS	Right Hand Side
RMS	Root Mean Square
RSRP	Reference Signal Received Power
RX	Receive
SC	Subcarrier Spacing
SCS	SubCarrier Spacing
SE	Spectrum Engineering
SINR	Signal-to-Interference-and-Noise Ratio
SIR	Signal to Interference Ratio
SNR	Signal-to-Noise Ratio
SRS	Sounding Reference Signal
SSB	Synchronization Signal Block
SVD	Singular Value Decomposition
TC	Technical Committee
TDD	Time Division Duplex
TDL	Tapped Delay Line
TPMI	Transmit Precoding Matrix Index
TPUT	Throughput
TTI	Transmission Time Interval
TX	Transmission
UE	User Equipment
UE/BS	User Equipment/Base Station
UIC	Union Internationale des Chemins de Fer
UL	UpLink
WI	Work Item

4 Assumptions and Parameters for Simulations and Evaluations

4.1 Introduction

Assumption and Parameters used by all Companies for the simulations and evaluations are summarized in clause A.3.3.1.

4.2 Scenarios

The objective is to define the minimum number of scenarios which cover most of the radio environment:

- Rural scenario:
    - High-speed segment at 350 km/h.
- Urban scenario:
    - High-density segment at 80 km/h.
    - Low-density segment at 80 km/h.
- Hilly scenario:
    - hilly will be investigated in a subsequent study.

4.3 System-related Parameters

4.3.1 Spectrum, system bandwidths and operation modes

4.3.1.1 900 MHz FDD

- 5 MHz channel bandwidth within 875 MHz to 880 MHz/920 MHz to 925 MHz frequency range.
- Subcarrier spacing 15 kHz.

4.3.1.2 1 900 MHz TDD

- 10 MHz channel bandwidth within 1 900 MHz to 1 910 MHz frequency range.
- Two UL/DL configurations to be considered: 50/50 and 90/10.
- Subcarrier spacing 15 kHz.

4.3.2 Transmit power assumptions

4.3.2.1 Downlink case

- BTS EIRP 900 MHz: 63 dBm (include feeder losses and antenna gain).
- BTS EIRP 1 900 MHz: 40 dBm and 63 dBm (include feeder losses and antenna gain).

4.3.2.2 Uplink case

- UE max. power classes:1 maximum output power of 31 dBm is considered.
- UE power class 2 maximum output power of 26 dBm might be considered (optional).
- UE power class 3 maximum output power of 23 dBm is considered.
- UE power control; open loop power control. Details are to be found in clause 4.6.2.3.11.

4.3.3 Antenna parametrization

4.3.3.1 Trackside/BS

As per parameters outlined in clause A.3.3.1:

- 900 MHz Antenna peak gain: 17 dBi
- 900 MHz BS feeder loss: 3 dB, [i.1]
- 1 900 MHz Antenna peak gain: 18 dBi
- 1 900 MHz BS feeder loss: 4 dB
- Horizontal polarization/3 dBm BW azimuth plane: 65°, [i.1]
- Vertical polarization/3 dBm BW elevation plane 8,5° ± 1,5°
- Downtilt: 0° - 3°
- Examples for antenna model used for parametrization:
    - Recommendation ITU-R F.1336-5 [i.10]
    - 3GPP 38 series reference antenna pattern

4.3.3.2 Train side/UE

- Within the present document, it is assumed that the UE antenna gain compensates the cable/feeder losses.

4.3.4 Multi-antenna/MIMO configurations under consideration

- Potential MIMO schemes 900 MHz:
    - Downlink: 2x1, 2x2, 4x1, 4x2
    - Uplink: 1x2, 2x2, 1x4, 2x4
- Potential MIMO schemes 1 900 MHz:
    - Downlink: 2x1, 2x2, 4x1, 4x2, 8x1, 8x2
    - Uplink: 1x2, 2x2, 1x4, 2x4, 1x8, 2x8
- Transmission diversity mode to be defined

4.3.5 Inter-site Interference mitigation method

- Baseline configuration is noted in each company approach.
- Constant frequency approach (Reuse Factor 1):
  In 3GPP, the baseline receiver agreed to be used for the simulations on the performance requirements is Minimum Mean Square Error (MMSE) - Interference Rejection Combining (IRC) receiver. The MMSE-IRC receiver has the capability to 'reject' the interference by creating a 'null' in the spatial domain towards the most dominant interferer, Company A and Company B are using MMSE-IRC receiver in both the BS and UE (see 3GPP TR 36.884 [i.9] Performance requirements of MMSE-IRC receiver for LTE BS).

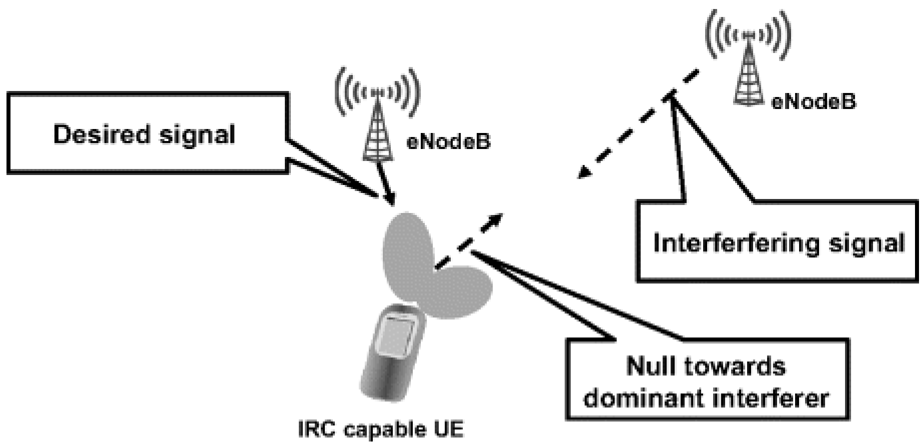

Figure 1: The MMSE-IRC receiver principle in the LTE context

- Fractional Frequency Reuse:
  COMPANY C is using this method.

4.4 Deployment-Related Parameters

4.4.1 Cellular layout

As per parameters outlined in clause A.5:

- Considered inter-site distances (ISD) using 900 MHz band:
  - Rural scenario: 8 km
  - Urban scenario: 2 km and 4 km

- Considered inter-site distances (ISD) using 1 900 MHz band:
  - Rural scenario: 4, 6 and 8 km
  - Urban scenario: 2 and 4 km
- BS antenna height:
  - Rural: 35 m
    (Company A has used 30 m for rural scenario)
  - Urban: 20 m
    (Company A has used 18 m for urban scenario)
- UE/Train antenna height: 4 m
- Tower to track distance: 15 m

4.4.2 Neighbour cell interference models

- To be documented for each simulation

4.4.3 Train and railway track assumptions

4.4.3.1 Common assumptions to all scenarios

- Two parallel tracks with specified inter-track distance of 3,5 m
- The following train densities are defined globally for 2 tracks