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Urban Rail ITS and Road ITS applications in the 5,9 GHz band; Investigations for the shared use of spectrum

Reference

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Foreword

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

Modal verbs terminology

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Executive summary

The present document answers to CEPT invitation to ETSI to develop sharing and interference mitigation techniques within three years, to ensure co-channel coexistence in the frequency range 5 875 MHz to 5 925 MHz between Road ITS and Urban Rail applications, and between Road ITS radio technologies, considering the following:

"Minimum technical requirements (without any change for Road ITS in 5875-5905 MHz):

- *the frequency band 5875-5 925 MHz is designated for all safety-related ITS applications (Road ITS and Urban Rail ITS);*
- *the frequency band 5 925-5935 MHz is designated for safety-related Urban Rail ITS applications;*
- *define priority to Road ITS applications below 5 915 MHz and to Urban Rail ITS applications above 5 915 MHz, so that protection is afforded to the application having priority;".*

CEPT Report 71 [i.12] also mentioned the fact that technical solutions already deployed should remain available for maintenance and evolution and the continued rollout of these systems should not be unduly hindered by a change of the spectrum regulatory environment.

The present document proposes methods to ensure co-channel coexistence in the frequency range 5 915 MHz to 5 925 MHz where Urban Rail is the priority application. No specific sharing methods for the operation of Urban Rail equipment in the Road ITS bands are considered.

The sharing techniques described in the present document are applicable to other frequency bands, if required to protect legacy CBTC systems (example: Malaga CBTC system uses the 5 905 MHz to 5 925 MHz band).

The present document proposes:

- Methods to define protected zones.
- Protected Zone detection methods.
- Mitigation techniques to apply in protected zones.

Regarding the definition of protected zones, several methods have been identified. A measurement campaign will be needed to validate these results and to confirm the simulation parameters which should be used to define the proper mitigation area to protect Urban Rail communications.

Considering Protected Zone detection, the present document evaluated several solutions, but the choice of the final one is still to be done among the following:

- Read-only database combined with alert beacons.
- Updatable database combined with optional permissive beacons.

Additional requirements such as regulatory, operational and installation aspects should be taken into account for final decision.

The two solutions described in the present document based on MAC/PHY layer may be considered as long-term solutions, however existing Urban Rail lines will not be protected. Urban Rail safety and availability concepts are essential and are not guaranteed. These solutions need further investigation before confirming feasibility.

Regarding the mitigation method, adjustment of Road ITS EIRP is a possible way and can be implemented. It could be a progressive reduction with several steps when approaching the urban Rail line, up to stopping transmission on Urban Rail channels. Indeed, in critical situations like parallel roads to the Urban Rail tracks (see Malaga example) an ITS device needs to stop using the relevant Urban Rail channel in the identified mitigation area.

It is recommended that:

- standards ETSI EN 302 571 [i.4] and ETSI TS 102 894-2 [i.3] are modified; and
- a new Technical Specification is developed to address detection and mitigation techniques outlined in the present document.

Introduction

Modern mass-transit Urban Rail systems run trains at short intervals - often 90 seconds apart, sometimes even less. To enable this in complete safety, automatic train control systems are employed, which drive the train, continuously supervise train speed and enforce safe separation between trains.

These systems require continuous, bidirectional data transmission from track to trains, for which radio has been increasingly used over the past fifteen years. Frequencies above 5 905 MHz are used on the basis of national authorizations in several countries (see Annex 1, Table 2b in CEPT Report 71 [i.12]) with proprietary radio technologies and protocols. These radio-based systems are known as Communications Based Train Control (CBTC) systems.

In the context of extensive use of the spectrum, and to enable Public Transport Operators to modernize existing systems and to plan new lines with CBTC, the need for a designated harmonized bandwidth for CBTC, with suitable quality of service, has been expressed in the ETSI TR 103 111 [i.17].

Later, ETSI TR 103 442 [i.10] was developed to present to the ECC a common point of view between TC ITS and TC RT, regarding sharing possibilities between CBTC and Road ITS applications in the 5 875 MHz to 5 925 MHz frequency band. CEPT WGFM invited ETSI to provide a detailed and agreed technical standard allowing practical implementation of both Urban Rail and Road ITS applications in the 5 875 MHz to 5 925 MHz band. At EU level, an ITS mandate has been prepared to study the extension of the upper edge of the EC harmonized safety-related ITS band (5 875 MHz to 5 905 MHz) by 20 MHz up to 5 925 MHz, and to allow Urban Rail (using Communication Based Train Control, (CBTC)) to use the EC harmonized safety-related ITS band.

CEPT Report 71 [i.12] also mentioned the fact that technical solutions already deployed should remain available for maintenance and evolution and the continued rollout of these systems should not be unduly hindered by a change of the spectrum regulatory environment.

CEPT Report 71 [i.12] responds to that mandate, inviting the European Commission to take into consideration the following improvements in the regulatory framework for ITS: "*The restriction to road transportation system should be withdrawn and should encompass all ground-based land transportation systems including Urban Rail*".

CEPT invited ETSI to develop sharing and interference mitigation techniques with a reasonable timeframe (no more than 3 years), to ensure co-channel coexistence in the frequency range 5 875 MHz to 5 925 MHz between Road ITS and Urban Rail applications, and between Road ITS radio technologies, considering the following:

"*Minimum technical requirements (without any change for Road ITS in 5875-5905 MHz):*

- *the frequency band 5875-5 925 MHz is designated for all safety-related ITS applications (Road ITS and Urban Rail ITS);*
- *the frequency band 5 925-5935 MHz is designated for safety-related Urban Rail ITS applications;*
- *define priority to Road ITS applications below 5 915 MHz and to Urban Rail ITS applications above 5 915 MHz, so that protection is afforded to the application having priority;".*

CEPT Report 71 [i.12] also mentioned the fact that technical solutions already deployed should stay available for maintenance and evolution and the continued rollout of these systems should not be unduly hindered by a change of the spectrum regulatory environment.

This situation is summarized in Figure 1.

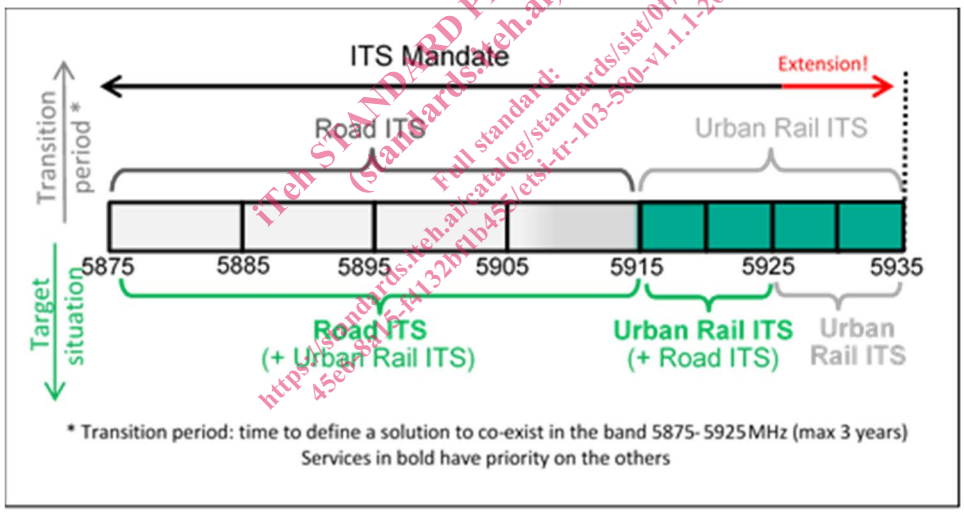

Figure 1: Road ITS and Urban Rail ITS bands

1 Scope

The present document proposes methods to ensure co-channel coexistence in the frequency range 5 915 MHz to 5 925 MHz where Urban Rail is the priority application.

In the present document, tramways are considered to be Road ITS because they are not segregated from road or pedestrian traffic.

NOTE 1: In the present document, no specific sharing methods for the operation of Urban Rail equipment in the Road ITS bands are considered given that Urban Rail equipment is not operating in these bands in areas where ITS equipment is active.

NOTE 2: The sharing techniques described in the present document are applicable to other frequency bands, if required to protect legacy CBTC systems (example: Malaga CBTC system uses the 5 905 MHz to 5 925 MHz band).

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 TS 102 792: "Intelligent Transport Systems (ITS); Mitigation techniques to avoid interference between European CEN Dedicated Short Range Communication (CEN DSRC) equipment and Intelligent Transport Systems (ITS) operating in the 5 GHz frequency range".

[i.2] ETSI EN 302 637-2: "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service".

[i.3] ETSI TS 102 894-2: "Intelligent Transport Systems (ITS); Users and applications requirements; Part 2: Applications and facilities layer common data dictionary".

[i.4] ETSI EN 302 571 (V2.1.1): "Intelligent Transport Systems (ITS); Radiocommunications equipment operating in the 5 855 MHz to 5 925 MHz frequency band; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU".

[i.5] ETSI EN 302 637-3 (V1.2.2): "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 3: Specifications of Decentralized Environmental Notification Basic Service".

[i.6] ETSI EN 302 663 (V1.2.1): "Intelligent Transport Systems (ITS); Access layer specification for Intelligent Transport Systems operating in the 5 GHz frequency band".

[i.7] ECC Report 101: "Compatibility studies in the band 5855 - 5 925 MHz between Intelligent Transports Systems (ITS) and others systems".

[i.8] ECC Report 228: "Compatibility studies between Intelligent Transport Systems (ITS) in the band 5855-5 925 MHz and other systems in adjacent bands".

[i.9] ETSI EN 302 665 (V1.1.1): "Intelligent Transport Systems (ITS); Communications Architecture".

[i.10] ETSI TR 103 442 (V1.1.1): "Railways Telecommunications (RT); Shared use of spectrum between Communication Based Train Control (CBTC) and ITS applications".

[i.11] ECC Report 290: "Studies to examine the applicability of ECC Reports 101 and 228 for various ITS technologies under EC Mandate (RSCOM 17-26Rev.3)".

[i.12] CEPT Report 71: "Report from CEPT to the European Commission in response to the Mandate to study the extension of the Intelligent Transport Systems (ITS) safety-related band at 5.9 GHz".

[i.13] IEEE 1474.1-2004™: "Communications-Based Train Control (CBTC) Performance and Functional Requirements".

[i.14] IEC 62290.1 (2014): "Railway applications - Urban guided transport management and command/control systems - Part 1: System principles and fundamental concepts".

[i.15] IEEE 802.11-2016™: "IEEE Standard for Information technology -- Telecommunications and information exchange between systems Local and metropolitan area networks -- Specific requirements -- Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications".

[i.16] ETSI EN 301 893 (V2.1.1): "5 GHz RLAN Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU".

[i.17] ETSI TR 103 111 (V1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); System Reference document (SRdoc); Spectrum requirements for Urban rail Systems in the 5,9 GHz range".

[i.18] ECC Report 68:"Compatibility studies in the band 5725-5875 MHz between Fixed Wireless Access (FWA) systems and other systems", Riga, June 2005.

[i.19] ETSI TR 102 492-1 (V1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Intelligent Transport Systems (ITS); Part 1: Technical characteristics for pan-European harmonized communications equipment operating in the 5 GHz frequency range and intended for critical road-safety applications; System Reference Document".

[i.20] ETSI TR 102 492-2: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Intelligent Transport Systems (ITS); Part 2: Technical characteristics for pan European harmonized communications equipment operating in the 5 GHz frequency range intended for road safety and traffic management, and for non-safety related ITS applications; System Reference Document".

[i.21] IEEE Transactions on Vehicular Technology: "A Measurement Based Mutlilink Shadowing Model for V2V Network Simulations of Highway Scenarios", Mikael G. Nilsson, Carl Gustafsol, Taimoor Abbas, Fredrik Tufvesson, Volume 66, pp 8632-8643.

[i.22] ETSI EN 302 931 (V1.1.1): "Intelligent Transport Systems (ITS); Vehicular Communications; Geographical Area Definition".

[i.23] 3GPP TR 36.786 (V14.0.0) (2017-03): "Vehicle-to-Everything (V2X) services based on LTE; User Equipment (UE) radio transmission and reception (Release 14)".

[i.24] ETSI TS 136 101 (V14.7.0) (2018-04): "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception (3GPP TS 36.101 version 14.7.0 Release 14)".

[i.25] CENELEC EN 50128: "Railway applications - Communications, signalling and processing systems - Software for railway control and protection systems".

[i.26] CENELEC EN 50129: "Railway applications - Communication, signalling and processing systems - Safety related electronic systems for signalling".

[i.27] Directive 2010/40/EU on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport.

[i.28] Regulation (EU) 2019/881 of the European Parliament and of the Council of 17 April 2019 on ENISA (the European Union Agency for Cybersecurity) and on information and communications technology cybersecurity certification and repealing Regulation (EU) No 526/2013 (Cybersecurity Act).

[i.29] ISO 3166-1: "Codes for the representation of names of countries and their subdivisions -- Part 1: Country codes".

[i.30] ISO 26262 (all parts): "Road vehicles -- Functional safety".

[i.31] IEC 62132-1:2015: "Integrated circuits - Measurement of electromagnetic immunity - Part 1: General conditions and definitions".

[i.32] ETSI TS 103 097: "Intelligent Transport Systems (ITS); Security; Security header and certificate format".

[i.33] ETSI TS 103 301: "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Facilities layer protocols and communication requirements for infrastructure services".

[i.34] Recommendation ITU-R P.2040-1: "Effects of building materials and structures on radio wave propagation above about 100 MHz".

[i.35] AEC - Q100: "Failure Mechanism Based Stress Test Qualification For Integrated Circuits".

[i.36] SAE J2735: "Dedicated Short Range Communications (DSRC) Message Set Dictionary™".

[i.37] Recommendation ITU-R F.1336-1:"Reference radiation patterns of omni-directional, sector and other antennas in point-to-multipoint systems for use in sharing studies in the frequency range from 1 GHz to about 70 GHz".

[i.38] Directive 2014/53/EU of the European Parliament and of the Council of 16 April 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1999/5/EC Text with EEA relevance.

3 Definition of terms, symbols and abbreviations

3.1 Terms

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

5 GHz ITS frequency band: band from 5 875 MHz to 5 925 MHz

Communications-Based Train Control (CBTC): Automatic Train Control (ATC) system using radio for train to wayside data communications

NOTE: The general functional requirements of CBTC systems have been standardized by the IEEE in IEEE 1474.1 [i.13], and by the IEC standard 62290.1 [i.14], which give the following definition:

A CBTC system is a continuous, automatic train control system utilizing:

- high-resolution train location determination, independent of track circuits;
- continuous, high-capacity, bidirectional train-to-wayside data communications; and
- trainborne and wayside processors capable of implementing Automatic Train Protection (ATP) functions, as well as optional Automatic Train Operation (ATO) and Automatic Train Supervision (ATS) functions.

dynamic detection method: method used by an ITS station to detect that it is in a geographical area where Urban Rail protection is requested only if there is a train in the area and therefore an actual need to mitigate

ITS station: station transmitting in the 5 GHz ITS frequency band, as defined as ETSI EN 302 665 [i.9]

movement authority: authorization for a train to run safely to a specific location

redundant: resilient, in that it has duplicated components that increase reliability

road ITS: ITS systems based on vehicle-to-vehicle, vehicle-to-infrastructure and infrastructure-to-infrastructure communications for the exchange of information between road vehicles and their environment

NOTE: In the present document Road ITS includes all kinds of ground based ITS except Urban Rail ITS systems.

static detection method: method used by an ITS station to detect that it is in a geographical area where Urban Rail protection is requested, even if there is no train in the area and therefore no actual need to mitigate

urban rail: public transport system permanently guided at least by one rail, intended for the operation of local, urban and suburban passenger services with self-propelled vehicles and segregated from general road and pedestrian traffic

urban rail ITS: urban rail system controlled by a CBTC application with communications operating in the 5 GHz ITS frequency band

NOTE: Trams are not included in this definition.

urban rail station: urban rail device transmitting CBTC messages in the 5 GHz ITS frequency band

vehicle: all types of land mobile device

3.2 Symbols

Void.

3.3 Abbreviations

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

ACK	ACKnowledgment
AP	Access Point
ASECAP	Association Européenne des Concessionnaires d'Autoroutes et d'Ouvrages à Péage (European Association of Operators of Road Tolling Infrastructure)
ASIL	Automotive Safety Integrity Level
ASN	Abstract Syntax Notation
ATC	Automatic Train Control
ATO	Automatic Train Operation
ATP	Automatic Train Protection
ATS	Automatic Train Supervision
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
BSS	Basic Service Set
CABS	Cooperative Awareness Basic Service
CAM	Cooperative Awareness Message
CBTC	Communications-Based Train Control
CCH	Control Channel
CDD	Common Data Dictionary
CEN	Comité Européen de Normalisation (European Committee for Standardization)
C-ITS	Cooperative Intelligent Transportation Systems
C-ITS-S	Central ITS Station
CRA	Communication Relevance Area
CS	Central Station
CSMA/CA	Carrier Sense Multiple Access with Collision Avoidance
CTS	Clear To Send
DCC	Decentralized Congestion Control
DE	Data Element
DEN	Decentralized Environmental Notification
DENM	Decentralized Environmental Notification Message
DF	Data Frame

DIFS	Distributed coordination function Interframe space
DSRC	Dedicated Short-Range Communications
DSSS	Direct Sequence Spread Spectrum
E2E	End-to-End
EIRP	Equivalent Isotropic Radiated Power
EMC	ElectroMagnetic Compatibility
FCS	Frame Check Sequence
FWA	Fixed Wireless Access
GN	GeoNetworking
GPS	Global Positioning System
HDR	High Data Rate
HF	High Frequency
ID	IDentity
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
ISO	International Standards Organization
ITS	Intelligent Transport Systems
ITS-G5	802.11p radio access technology in the 5,9 GHz band
ITS-S	Intelligent Transport Systems Station
ITU-R	International Telecommunication Union - Radio
LDM	Local Dynamic Map
LF	Low Frequency
LFS	propagation Loss
LoS	Line of Sight
MAC	Medium Access Control
MAP	Map data
MCL	Minimum Coupling Loss
MCO	MultiChannel Operation
NLOS	No Line of Sight
OBU	On Board Unit
OCB	Outside the Context of a BSS
OEM	Original Equipment Manufacturer
OFDM	Orthogonal Frequency-Division Multiplexing
OOB	Out Of Band
PHY	PHYsical
PKI	Public Key Infrastructure
PR	Protection Ratio
PSD	Plateform Screen Doors
PZ	Protected Zone
PZM	Protected Zone Message
QPSK	Quadrature Phase Shift Keying
RATP	Régie Autonome des Transport Parisien (Metro operator of Paris)
RER	Reseau Express Regional (suburban metro lines in Paris)
RF	Radio Frequency
RSU	Road Side Unit or Rail Side Unit
RTS	request To Send
RX	Receiver
S_RX	Signal Received
S_TX	Signal Transmitted
SAE	Society of Automotive Engineers
SIFS	Short Interframe Spece
SPAT	Signal Phase and Timing
TDD	Time Division Duplexing
TDMA	Time Division Multiple Access
T-ITS-S	Train ITS Station
TPC	Transmit Power Control
TS	Technical Specification
TS	Terminal Station
TS-ITS-S	Track Side ITS Station
TX	Transmiter
UDP	User Datagram Protocol