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TECHNICAL REPORT

Urban Rail ITS and Road ITS applications in the 5,9 GHz band; Measurement campaign to confirm simulation parameters to define Urban Rail ITS protected zones in 5 915 MHz to 5 925 MHz

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Foreword

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

Modal verbs terminology

In the present document "**should**", "**should not**", "**may**", "**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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Executive summary

ETSI TR 103 580 [i.2] described possible sharing and interference mitigation techniques between Road ITS and Urban Rail ITS. These techniques would allow the technical implementation of the regulatory priority regime afforded to Urban Rail ITS in the spectrum band 5 915 MHz to 5 925 MHz.

ETSI TR 103 580 [i.2] concluded that a measurement campaign would be needed to validate the results and the simulations parameters applicable for the definition of the protected zones, where mitigation techniques would be required.

The present document describes the work undertaken to perform the required measurements and analyses the resulting data. The following items are covered:

- Identification of relevant test cases representative of typical coexistence situations.

- Identification of relevant areas to conduct the measurements.
- Description of test procedures and test tools.
- Detailed plan of the measurements.
- Analysis of the measurements campaign.
- Conclusion on the results.

The analysis confirms that the levels received by urban rail ITS, from vehicles transmitting with the maximum allowed output power of 33 dBm/10 MHz EIRP and driving in the surrounding of a metro Line, are above the defined protection levels of the CBTC communications.

Although the received levels in the present document are displayed for vehicles transmitting at maximum output power (23 dBm/MHz, i.e. 33 dBm per a 10 MHz channel as defined in Commission Implementing Decision (EU) 2020/1426 [i.8]), the results could be scaled down for different transmit powers (e.g. 10 dB decrease for vehicles transmitting 23 dBm/10 MHz).

The aggregated power from multiple vehicles interfering has not been investigated in the present document, however this could be investigated later with the measurement data available.

The assessment of interference on CBTC systems is outside the scope of the present document. Following the measurement campaign presented in the present document, a revision of ETSI TR 103 580 [i.2] will be required. The revision will focus on identifying the most appropriate mitigation technique. This will be the basis of future normative work allowing sharing of the spectrum band 5 915 MHz to 5 925 MHz between Urban Rail and Road ITS.

Introduction

Commission Implementing Decision (EU) 2020/1426 [i.8] designates the band 5 875-5 935 MHz for intelligent transport systems and limits it to urban rail ITS in 5 925 to 5 935MHz. [i.8] also states that "*Road ITS applications shall have priority below 5 915 MHz and urban rail ITS applications shall have priority above 5 915 MHz, so that protection is afforded to the application having priority" and further instructs that "Access by road ITS to the frequency range 5 915-5 925 MHz shall be limited to applications involving infrastructure-to-vehicle (I2V) connectivity only, coordinated, where appropriate, with urban rail ITS*"

The sharing and interference mitigation techniques would enable the technical implementation of the priority regime afforded to Urban Rail ITS.

One key concept introduced in ETSI TR 103 580 [i.2] is the "Urban rail protected zones" which should be used to define the mitigation areas to protect Urban Rail communications. ETSI TR 103 580 [i.2] concluded that a measurement campaign would be needed to validate the results and the simulation parameters applicable for the definition of the protected zones.

In the present document, a set of measurement scenarios are defined together with a set of relevant areas, on two metro Lines, where measurements have been performed. The measurement setup, procedures and planning are also introduced. After completion of the measurement campaign, the measurements have been analysed and the results of these analysis are presented.

The measurements performed on the three sections of RATP Line 6 and on the 3 sections of RATP Line 8, both in Paris, with trains and base stations, confirm the levels received by trains and base stations from vehicles transmitting with the maximum allowed output power of 33 dBm/10 MHz EIRP and driving on parallel roads, on bridge above or below the tracks and in different areas in the surrounding of a metro Line are above the defined protection levels of the CBTC communications. This result could be hypothesized already from the simulations of propagation performed previously and aiming at identifying the relevant areas.

1 Scope

The present document describes the work undertaken to perform the required measurements, and analyses the resulting data. The following items are covered:

- Identification of relevant test cases representative of typical coexistence situations.
- Identification of relevant areas to conduct the measurements.
- Description of test procedures and test tools.
- Detailed plan of the measurements.
- Analysis of the measurements campaign.
- Conclusion on the results.

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 regarding a particular subject area.

[i.1] Commission Decision 2008/671/EC on the harmonised use of radio spectrum in the 5875 - 5905 MHz frequency band for safety related applications of Intelligent Transport Systems (ITS).

[i.2] ETSI TR 103 580 (V1.1.1) (2019-08): "Urban Rail ITS and Road ITS applications in the 5,9 GHz band; Investigations for the shared use of spectrum".

[i.3] 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.4] ECC Report 101: "Compatibility studies in the band 5855 - 5 925 MHz between Intelligent Transports Systems (ITS) and other systems".

[i.5] ECC Report 68:"Compatibility studies in the band 5725-5875 MHz between Fixed Wireless Access (FWA) systems and other systems", Riga, June 2005.

[i.6] 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.7] Recommendation ITU-R P.1411-6: "Propagation data and prediction methods for the planning of short-range outdoor radiocommunication systems and radio local area networks in the frequency range 300 MHz to 100 GHz".

[i.8] Commission Implementing Decision (EU) 2020/1426 of 7 October 2020 on the harmonised use of radio spectrum in the 5 875-5 935 MHz frequency band for safety-related applications of intelligent transport systems (ITS) and repealing Decision 2008/671/EC.

[i.9] Z. Živković, D. Senić, C. Bodendorf, J. Skrzypczynski and A. Šarolić: "Radiation pattern and impedance of a quarter wavelength monopole antenna above a finite ground plane", SoftCOM 2012, 20th International Conference on Software, Telecommunications and Computer Networks, 2012, pp. 1-5.

[i.10] A. Kwoczek, Z. Raida, J. Láčík, M. Pokorny, J. Puskelý and P. Vágner: "Influence of car panorama glass roofs on Car2Car communication (poster)", 2011 IEEE Vehicular Networking Conference (VNC), 2011, pp. 246-251, doi: 10.1109/VNC.2011.6117107.

[i.11] IEEE 802.11p™: "IEEE Standard for Information technology-- Local and metropolitan area networks-- Specific requirements-- Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 6: Wireless Access in Vehicular Environments".

[i.12] Ublox receiver ZED F9R Product sheet.

[i.13] Recommendation ITU-R F.1336:"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.14] HTZ Communications - brochure.

NOTE: Available at https://atdi.com/products-and-solutions/htz-communications.

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:

ADR	Automotive Dead Reckoning
BS	Base Station
C/I	Carrier to Interference ratio
CBTC	Communications-Based Train Control systems
CEPT	European Conference of Postal and Telecommunications Administrations
dB	Decibel
dBi	Decibel isotropic
dBm	decibel-milliwatts
DCC	Decentralized Congestion Control
DHCP	Dynamic Host Configuration Protocol
DNS	Domain Name Server
DSRC	Dedicated Short-Range Communications
EC	European Commission
ECC	Electronic Communications Committee
EIRP	Equivalent Isotopically Radiated Power
EMSL	European Microwave Signature Laboratory
ETSI	European Telecommunications Standards Institute

EU	European Union
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HTTP	HyperText Transfer Protocol
I2V	Infrastructure to-Vehicle
IMU	Inertial Measurement Unit
IP	Internet Protocol
ITS	Intelligent Transport Systems
ITS-G5	Intelligent Transport Systems operating in the 5 GHz frequency band
JRC	DG Joint Research Centre of EC
LoS	Line-of-Sight
LTE	Long Term Evolution
NA	Non Applicable
NLoS	Non-Line of Sight
NRTK	Network Real Time Kinematic
NTRIP	Network Transport of RTCM via Internet Protocol
OBU	Onboard Unit
OCC	Operation Control Centre
OEM	Original Equipment Manufacturer

NOTE: A term in the automotive industry used for the vehicle manufacturers.

OSR	Observation Space Representation
QPSK	Quadrature Phase-Shift Keying
QZSS	Quasi-Zenith Satellite System
RATP	Régie Autonome des Transports Parisiens

NOTE: State-owned public transport operator and maintainer Metro of Paris.

RF	Radio Frequency
RSSI	Received Signal Strength Indicator
RTCM	Radio Technical Commission for Maritime
RTK	Real Time Kinematic
Rx	Receiver
SBAS	Satellite-Based Augmentation System
SUV	Sports Utility Vehicle
TR	Technical Report
Tx	Transmitter
V2V	Vehicle to Vehicle
V2X	Vehicle to anything communication
VPN	Virtual Private Network
WGS 84	World Geodetic System 1984

4 Measurement campaign context and organization

4.1 General

In October 2017, the European Commission mandated CEPT/ECC to provide the Commission with the necessary information to consider the amendment of Commission Decision 2008/671/EC [i.1] of 5 August 2008, on the harmonised use of radio spectrum in the 5 875 MHz to 5 905 MHz frequency band for safety-related applications of Intelligent Transport Systems (ITS).

In particular, the purpose of the EC ITS mandate to the CEPT was to study the possibility of:

- Extending the upper edge of the EC harmonised safety related ITS band (5 875 MHz to 5 905 MHz) by 20 MHz up to 5 925 MHz.
- In addition to road transport, allowing other means of transport such as Urban Rail (using Communication Based Train Control (CBTC)) in the EC harmonised safety related ITS band.

CEPT/ECC concluded in CEPT Report 71 [i.6] and 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, by considering the following (see also Figure 1):

"*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;"*

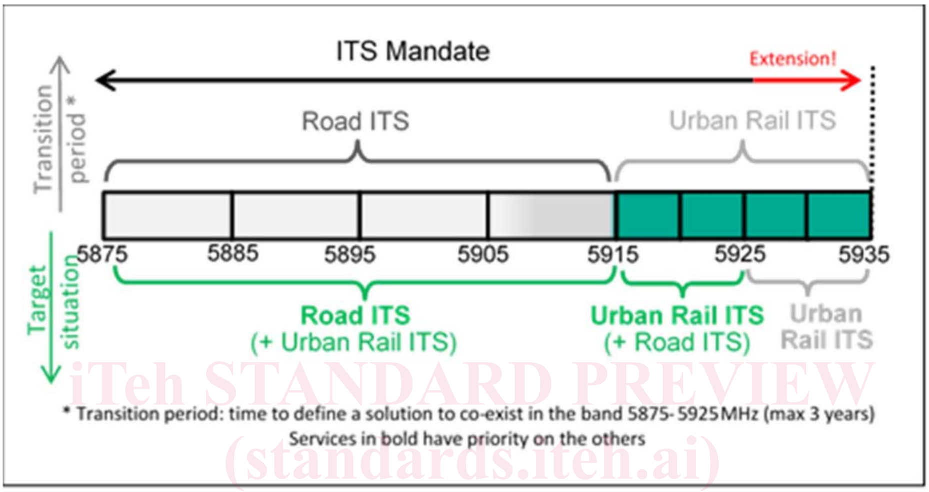

Figure 1: Road ITS and Urban Rail ITS bands

4.2 Available results and studies

ETSI has been conducting studies since 2017 and the outcome was summarized in ETSI TR 103 580 [i.2]. ETSI TR 103 580 [i.2] focused on the 5 915 MHz to 5 925 MHz band where Urban Rail ITS would have priority and proposed the following:

- Identify methods to define protected zones.
- Define Protected Zone detection methods.
- Define mitigation techniques to apply in protected zones.

Regarding the definition of protected zones, several methods have been identified. ETSI TR 103 580 [i.2] concluded the need to conduct a measurement campaign 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 systems.

ETSI TR 103 580 [i.2] also concluded that further studies are needed on:

- The protected zone detection methods, in particular:
  - Read-only database combined with alert beacons.
  - Updatable database combined with optional permissive beacons.
- The mitigation techniques to apply in protected zones.

5 Critical interference scenarios

5.1 Description of critical interference scenarios

5.1.1 Introduction

A metro Line can leave a tunnel for different reasons:

- At the end of the Line, the last station may be in open air followed by a transfer track where several switches will distribute the trains to entrances in the depot.
- In suburban area, long section of Line can be in open air because there is more place than in a dense urban area and in this case an expensive tunnel is not justified.
- In a dense urban area, a metro Line can leave a tunnel because the underground does not allow to drill a tunnel at an acceptable cost. In this case the metro Line may run on a viaduct.

A metro Line in open air can have:

- One road parallel on one side of the track.
- Two roads parallel to the track with one parallel to each side.
- The tracks and the road can be at different levels:
  - tracks and road at the same level;
  - tracks on a viaduct or road on a viaduct.

A metro Line in open air can be on a viaduct or a bridge and cross a road. A road on a bridge can also cross a metro Line in open air.

It is also important to consider that a CBTC base station antenna can receive transmission from different areas in a city. Several vehicles present in each area can exchange messages. In each area these ones can receive each other and limit the use of the channel capacity at 62 % with the DCC; but vehicles in the different areas are not able to listen each other.

Because a CBTC base station has two high gain antennas pointing in two opposite directions, it can receive interference from several areas and "see" a channel occupancy much higher than 62 %.

5.1.2 Road parallel to Urban Rail tracks

Road parallel to urban rail tracks is a common situation that can be encountered in European cities as shown in Figure 2, Figure 3 and Figure 4.

Figure 2: Parallel road, Metro of Bruxelles (image source: http://transporturbain.canalblog.com/pages/bruxelles---du-tramway-souterrain-au-metro-automatique/34966419.html

Figure 2 shows a metro Line in open air surrounded with two parallel roads, one with two lanes on the right and one with one lane on the left.

Figure 3: Parallel road, Metro of Malaga (Map Source Google Earth: © Google)

Figure 3 shows a metro Line in open air that has a two lanes parallel road, while in Figure 4 the metro Line in open air is surrounded by two parallel roads having two lanes.

Figure 4: Parallel road Metro Line 8 of Paris (Map Source Google Earth: © Google)

In Figure 4 the distance between the axis of a track and the axis of the closest lane of the road varies between 7 m and 12 m. The tracks and the roads are at the same level or with a difference of level of maximum 1 m due to the ballast.

In some Lines, inside a city, the metro Line can leave the tunnel and continue on a viaduct. The viaduct can be surrounded by two roads as shown in Figure 5.

Figure 5: Metro Line 6 of Paris on a viaduct with parallel road and crossing road (Map Source Google Earth: © Google)

During peak business hours, traffic jam can be expected meaning a significant number of vehicles on the roads. On a section of metro Line of 1 km, one train can run every minute.

5.1.3 Road crossing Rail tracks

In suburban area a road can cross metro Line on a bridge as shown in Figure 6.

Figure 6: Metro Line 8 of Paris on a bridge crossing a road (Map Source Google Earth: © Google)

In a suburban area, a metro Line in open air can also cross a road being on a viaduct or a bridge as shown in Figure 7.

Figure 7: Road on a bridge crossing metro Line 8 of Paris (Map Source Google Earth: © Google)

The typical height of the track or the road above the ground is between 5 m to 6 m.

A CBTC base station antenna may be installed on or under a bridge for situation shown in Figure 6 and Figure 7.

5.1.4 Isles (group of vehicles) in a city or multiple RF sources

Figure 8 illustrates the scenario where the transmissions from multiple groups of vehicles are received by a CBTC base station or a train.

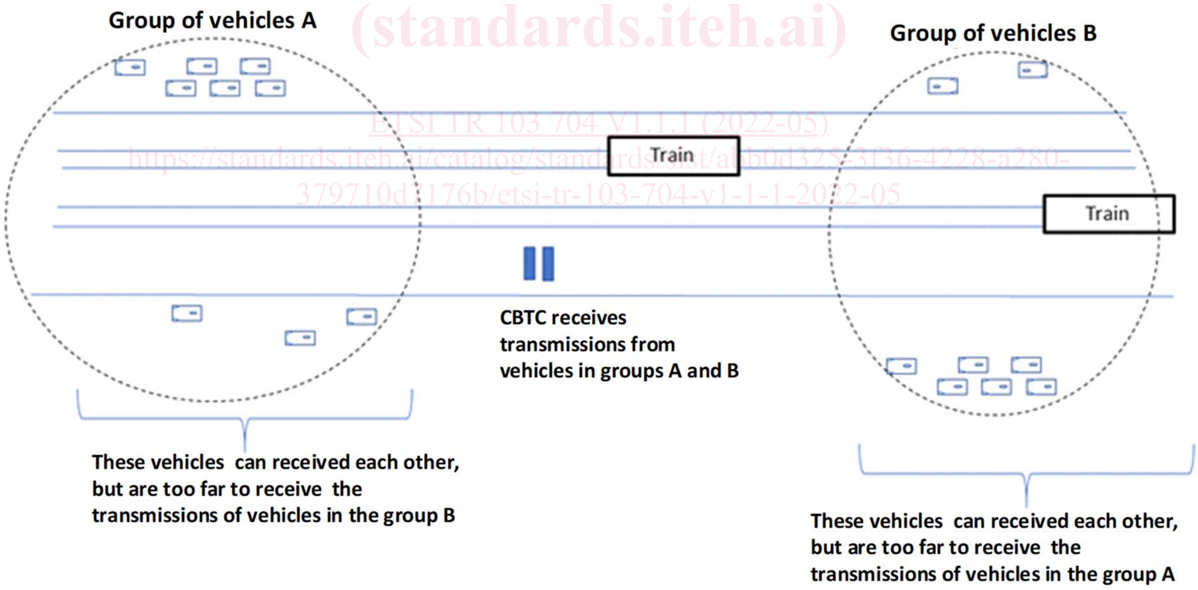

Figure 8: Isles in a city

Each group of vehicles can reach the channel occupancy limits of 62 % but the vehicles of the different groups are not able to listen each other. The CBTC base station has two high antennas pointing to two opposite directions to cover the track and the height of the CBTC base station above the ground is 5 m to 6 m. It means that a CBTC base station can receive transmissions of vehicles from different groups.

5.2 Summary

Table 1 below lists all the scenarios that have been considered.