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Contents

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM).

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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Executive Summary

The present document describes the spectrum requirements for the following communications of urban rail systems:

- primarily trackside/infrastructure-to-train communications; and
- optionally train-to-train communications.

Standardisation work is currently ongoing in the ESOs related to EC mandate M/486 EN "for programming and standardisation addressed to the European Standardisation Bodies in the field of Urban Rail" [i.12]. The rationale for this mandate from the European Commision is to reduce the greenhouse gas emissions, which come for a large portion from urban areas and urban transport. Urban rail is seen as one of the prominent solutions to offer the public other ways of transportation while supporting a modal shift from private car and increasing demand for public transport thanks to the economies of scale and to the administrative simplification.

In addition, since the European rail industry is a world leader, the technical harmonisation of urban rail would be beneficial not only from the environmental point of view but also from the competitiveness point of view.

The spectrum requirements cover the needs for:

1) fundamental time-critical CBTC and safety relevant applications with very low latency; and
2) non-safety relevant applications, applying mobile networking based on internet protocol as well as other protocols, extending the applicability of the communications equipment towards railway traffic management tasks and other applications.

Both of these types of applications might indirectly enhance the traffic safety and system operation.

CBTC is providing automatic train control with or without driver. To drive automatically a train, a Data Communication System is needed. When trains are moving the wireless system allows communication with a central system. The wireless system is used to transmit traction order or breaking order in a safe mode. If trains cannot transmit messages, they will not be authorized to move.

Each train sends its location 5 times a second and the central system sends an authorization to move for each train in the line. All the messages use the wireless DCS. This system allows to reduce the time between trains in automatic mode (85 s instead of 105 s with human drivers)

It is recommended to have contiguous and/or nearby frequency bands, in the upper 5 GHz frequency range designated for items 1 and 2. It is proposed:

- for item 1: to designate 20 MHz of spectrum for CBTC and safety relevant critical applications, preferably within the frequency range from 5,905 GHz to 5,925 GHz;
- for item 2: to designate 20 MHz of spectrum, i.e. 5,855 GHz to 5,875 GHz, for non-safety related urban rail applications (secure control, railway traffic management and video-surveillance).

It also requested to consider in a future review of the proposed ECC Decision the designation of 5,925 GHz to 5,945 GHz for future Urban Rail applications.

Spectrum usage as proposed in the present document is to be considered on a pan-European basis. In addition to the benefits expected from technical harmonization, the aim is to avoid coordination/protection zone issues at borders, and to facilitate any deployment in urban areas crossing borders.

Introduction

The present document has been developed to support the co-operation between ETSI and the Electronic Communications Committee (ECC) of the European Conference of Post and Telecommunications Administrations (CEPT).

Status of pre-approval draft

The present document was developed by TC RT in cooperation with the UITP Spectrum User Group. An earlier version underwent internal enquiry ERM(12)DEC058 by TC ERM. The comments received during that internal enquiry have been considered when preparing the current version. The present document contains final information.

1 Scope

The present document describes urban rail systems which may require a change of the present frequency designation/utilisation within CEPT.

It includes in particular:

- market information;
- technical information including expected sharing and compatibility issues;
- regulatory issues.

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] ECC/DEC/(08)01: ECC Decision of 14 March 2008 on the harmonised use of the 5875-5925 MHz frequency band for ITS, and subsequent amendments.

[i.2] ECC/DEC/(04)08 of 12 November 2004 on the harmonised use of the 5 GHz frequency bands for the implementation of Wireless Access Systems including Radio Local Area Networks (WAS/RLANs).

[i.3] IEEE 802.11p-2010: "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. Amendment 6: Wireless Access in Vehicular Environments (WAVE)".

[i.4] ETSI EN 302 665 V1.1.1 (2010-09): "Intelligent Transport Systems (ITS); Communications Architecture".

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

[i.6] ISO 21215: "Intelligent Transport Systems -- CALM -Medium and long range, high speed, air interface parameters and protocols for broadcast, point-point, vehicle-vehicle, and vehicle-point communications in the ITS Sector -- Air interface using 5 GHz communications".

[i.7] ETSI EN 302 571: "Intelligent Transport Systems (ITS); Radiocommunications equipment operating in the 5 855 MHz to 5 925 MHz frequency band; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive".

[i.8] MODURBAN, FP6 Project TIP4-2005-516380, MODCOMM Subproject, D39: "Data Communication System functional requirements".

NOTE: Modurban public documents are available at http://www.modurban.org/documents.php.

[i.9] MODURBAN, FP6 Project TIP4-2005-516380, MODCOMM Subproject, D40: "Data Communication System performance, reliability and maintainability requirements".

NOTE: Modurban public documents are available at http://www.modurban.org/documents.php.

[i.10] MODURBAN, FP6 Project TIP4-2005-516380, MODCOMM Subproject, D41: "Data Communication System Architecture".

NOTE: Modurban public documents are available at http://www.modurban.org/documents.php.

[i.11] CENELEC EN 50159: "Railway applications - Communication, signalling and processing systems - Safety-related communication in transmission systems".

[i.12] EC Mandate M/486 EN: "Mandate for Programming and Standardisation addressed to the European Standardisation bodies in the field of urban rail".

NOTE: This mandate is available at http://www.etsi.org/about/our-role-in-europe/public-policy/ec-mandates.

[i.13] Directive 2008/57/EC of the European Parliament and of the Council of 17 June 2008 on the interoperability of the rail system within the Community.

[i.14] MODSAFE European Commission Seventh Framework Programme MODSafe Modular Urban Transport Safety and Security Analysis Glossary Deliverable D.5.

NOTE: The MODSAFE Glossary is available at www.modsafe.eu.

[i.15] EN 14383-1:2006: CEN/TC 325 "Prevention of crime - Urban planning and building design - Part 1: Definition of specific terms".

[i.16] draft IEC 61375-2-6 Ed. 1.0: "Electronic railway equipment - Train Communication Network - Part 2-6: On-board to ground communication".

[i.17] CEPT/ERC Recommendation 70-03: "Relating to the Use of Short Range Devices (SRD)", Tromso 1997, Subsequent amendments 07 February 2014".

[i.18] Commission Decision of 5 August 2008 on the harmonised use of radio spectrum in the 5875-5905 MHz frequency band for safety-related applications of Intelligent Transport Systems (ITS) (2008/671/EC).

[i.19] ECC Recommendation (08)01: "Use of the band 5855-5875 MHz for Intelligent Transport Systems (ITS)".

[i.20] Commission Decision of 11 July 2005 on the harmonised use of radio spectrum in the 5 GHz frequency band for the implementation of wireless access systems including radio local area networks (WAS/RLANs)(2005/513/EC).

[i.21] Commission Implementing Decision of 11 December 2013 amending Decision 2006/771 on harmonisation of the radio spectrum for use by short-range devices and repealing Decision 2005/928/EC (2013/752/EU).

[i.22] ERC Report 25, version February 2013: "The European table of frequency allocations and applications in the frequency range 8.3 kHz to 3000 GHz (ECA table)".

[i.23] Recommendation ITU-R M.1453-2: "Intelligent transport systems - dedicated short range communications at 5.8 GHz".

[i.24] Report Recommendation ITU-R M.2228: "Advanced intelligent transport systems (ITS) radiocommunications".

[i.25] Recommendation ITU-R F.699: "Reference radiation patterns for fixed wireless system antennas for use in coordination studies and interference assessment in the frequency range from 100 MHz to about 70 GHz".

[i.26] CEPT/ERC Recommendation 74-01E (Siófok 98, Nice 99, Sesimbra 02, Hradec Kralove 05, Cardiff 11): "Unwanted emissions in the spurious domain".

[i.27] Agence Nationale de Fréquences, Commission de la Compatibilité Electromagnétique, 5 January 2010: "Rapport d"étude sur la compatibilité à 5.9 GHz entre les sytèmes RATP et les ITS".

[i.28] European Commission, Radio Spectrum Committee, document RSCOM13-32rev3: "Mandate to CEPT to study and identify harmonised compatibility and sharing conditions for Wireless Access Systems including Radio Local Area Networks in the bands 5350-5470 MHz and 5725-5925 MHz ("WAS/RLAN extension bands") for the provision of wireless broadbands services".

[i.29] CEPT/ECC document ECC(14)025 Annex 12: "Interim Report from CEPT to the European Commission in response to the Mandate To study and identify harmonised compatibility and sharing conditions for Wireless Access Systems including Radio Local Area Networks in the bands 5350-5470 MHz and 5725-5925 MHz ("WAS/RLAN extension bands") for the provision of wireless broadband services".

[i.30] ITU Radio Regulations, 2012.

[i.31] ETSI ES 202 663: "Intelligent Transport Systems (ITS); European profile standard for the physical and medium access control layer of Intelligent Transport Systems operating in the 5 GHz frequency band".

[i.32] ETSI EN 302 502: "Broadband Radio Access Networks (BRAN); 5,8 GHz fixed broadband data transmitting systems; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive".

[i.33] ECC/REC(06)04: "Use of the band 5 725-5 875 MHz for Broadband Fixed Wireless Access (BFWA)".

[i.34] ETSI EN 300 440: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short range devices; Radio equipment to be used in the 1 GHz to 40 GHz frequency range".

[i.35] ETSI EN 302 372: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Equipment for Detection and Movement; Tanks Level Probing Radar (TLPR) operating in the frequency bands 5,8 GHz, 10 GHz, 25 GHz, 61 GHz and 77 GHz".

[i.36] ETSI EN 302 217: "Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas".

[i.37] ETSI EN 301 443: "Satellite Earth Stations and Systems (SES); Harmonized EN for Very Small Aperture Terminal (VSAT); Transmit-only, transmit-and-receive, receive-only satellite earth stations operating in the 4 GHz and 6 GHz frequency bands covering essential requirements under article 3.2 of the R&TTE Directive".

[i.38] ERC/REC 12-02: "Harmonised radio frequency channel arrangements for analogue and digital terrestrial fixed systems operating in the band 12.75 GHz to 13.25 GHz".

[i.39] ECC/DEC/(11)02: ECC Decision of 11 March 2011 on industrial Level Probing Radars (LPR) operating in frequency bands 6 - 8.5 GHz, 24.05 - 26.5 GHz, 57 - 64 GHz and 75 - 85 GHz.

[i.40] ETSI EN 302 729: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Level Probing Radar (LPR) equipment operating in the frequency ranges 6 GHz to 8,5 GHz, 24,05 GHz to 26,5 GHz, 57 GHz to 64 GHz, 75 GHz to 85 GHz".

[i.41] ETSI EN 302 065: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD) using Ultra Wide Band technology (UWB) for communications purposes; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive".

[i.42] ETSI EN 302 500: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD) using Ultra WideBand (UWB) technology; Location Tracking equipment operating in the frequency range from 6 GHz to 9 GHz".

[i.43] ERC/REC 14-02: "Radio-frequency channel arrangements for medium and high capacity analogue and high capacity digital radio-relay systems operating in the band 6425-7125 MHz".

3 Definitions and abbreviations

3.1 Definitions

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

Data Communication System (DCS): global communication architecture into which radiocommunication links are integrated

NOTE: The Data Communication System is specified in [i.8], [i.9] and [i.10].

on-board unit: antenna**,** radio frequency accessories, radio transmitter and receiver, usually installed in a train

physical security: part of security concerned with measures and concepts designed to:

1) safeguard personnel;

2) prevent unauthorized access to equipment, installations, material and documents; and

3) safeguard equipment, installations, material and documents against espionage, sabotage, damage and theft

NOTE 1: This definition is from the European project MODSAFE (www.modsafe.eu) Glossary Deliverable D.5 [i.14] which are based on definitions from EN 14383-1 [i.15].

NOTE 2: See also "Security".

safety: freedom from unacceptable levels of risks resulting from unintentional acts or circumstances [i.11]

NOTE: This definition is from [i.14].

security: freedom from unacceptable levels of risks resulting from intentional acts or circumstance

NOTE 1: This definition is from [i.14].

NOTE 2: See also "Physical security".

Track-Side Unit: antenna**,** radio frequency accessories, radio transmitter and receiver, usually fixed as part of the railway infrastructure:

- installed along the track, e.g. on a gantry or a tunnel ceiling above it or at poles beside it;
- single TSUs operating in a stand-alone fashion; or
- a group of TSUs connected together by an appropriate infrastructure, which may include an information network; or
- a single TSU connected to an information network.

trackside-to-train communications: downlink communications

NOTE: See also trackside-train communications.

trackside-train communications: generic expression for communications between a trackside and a train, which may include both downlink and uplink communications

NOTE: These may be based on mobility mechanisms between adjacent Track-Side Units.

train-to-trackside communications: uplink communications

train-to-train communications: generic expression for bi-directional communications between trains

Urban Guided Transport systems (UGT): public transport systems permanently guided at least by one rail, intended for the operation of local, urban and suburban passenger services with self-propelled vehicles and operated either segregated or not from general road and pedestrian traffic

urban rail systems: cover both Urban Guided Transport systems (UGT) and other rail systems which might be excluded from the scope of the Interoperability Directive 2008/57/EC [i.13] (Article 1.3 (a) and (b)):

a) Metros, Trams and other Light Rail systems.

b) Networks that are functionally separate from the rest of the rail system and are intended only for the operation of local, urban or suburban passenger services, as well as railway undertakings operating solely on these networks.

3.2 Abbreviations

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

ANFR	Agence Nationale des FRequences
ARCEP	Autorité de Régulation des Communications Electroniques et de la Poste (ARCEP replaced ART)
ART	Autorité de Régulation des Télécommunications (French Regulatory Authority)
ATC	Automatic Train Control
BFWA	Broadband Fixed Wireless Access
CALM	Communications Access for Land Mobiles
CBTC	Communication-Based Train Control
CEPT	Conférence des administrations Européennes des Postes et Telecommunications
dBm	Power in decibels relative to 1 Mw
DCS	Data Communication System
DFS	Dynamic Frequency Selection
DSRC	Dedicated Short Range Communication
ECC	Electronic Communication Committee
EIRP	Equivalent Isotropically Radiated Power
ERC	European Radiocommunications Committee
ERM	Electromagnetic compatibility and Radio spectrum Matters
FSS	Fixed Satellite Service
HAPS	High Altitude Platform Station
IEEE	Institution of Electrical and Electronic Engineers
IP	Internet Protocol
ISM	Industrial, Scientific and Medical
ISO	International Standards Organisation
ITS	Intelligent Transport Systems
ITS-G5A	Frequency band ranging from 5 875 MHz to 5 905 MHz
ITS-G5B	Frequency band ranging from 5 855 MHz to 5 875 MHz
ITS-G5C	Frequency band ranging from 5 470 MHz to 5 725 MHz
ITS-G5D	Frequency band ranging from 5 905 MHz to 5 925 MHz
kbps	kilobits per second
LOS	Line Of Sight
LPR	Level Probing Radar
Mbps	Megabits per second
MODCOMM	MODURBAN Communications systems
MODURBAN	Modular Urban Guided Rail Systems
NLOS	Non Line Of Sight
OBU	On-Board Unit
QPSK	Quadrature Phase Shift Keying

RATP	Régie Autonome des Transports Parisiens
RF	Radio Frequency
RLAN	Radio Local Area Network
ROI	Return On Investment
RR	Radio Regulations
RT	Railway Telecommunications
RTTT	Road Transport and Traffic Telematics
SATCOM	Satellite Communications
SNCF	Société Nationale des Chemins de Fer
SYTRAL	Syndicat des Transports de l'Agglomération Lyonnaise (Public Authority)
TLPR	Tank Level Probing Radar
TP	Transmission Power
TPC	Transmit Power Control
TR	ETSI Technical Report
TSU	Track-Side Unit
TTT	Transport and Traffic Telematics
UGT	Urban Guided Transport systems
UITP	International Association of Public Transport (Union Internationale des Transports Publics)
UWB	Ultra-wideband
V2R	Vehicle-to-Roadside (ITS)
V2V	Vehicle-to-Vehicle (ITS)
VLBI	Very Long Baseline Interferometry
WAS	Wireless Access System
WAVE	Wireless Access in Vehicular Environments

4 Comments on the System Reference Document

4.1 Statements by ETSI Members

Comments from TC ITS:

During the commenting phases of the present document, one important comment regarding using the same protocol as ITS-G5 was not answered.

TC ITS would like to point out that the proposed spectrum (5 915 MHz to 5 935 MHz) overlaps with spectrum currently assigned to ITS-G5 (see ECC DEC(08)01 [i.1], 5 915 MHz to 5 925 MHz). This spectrum is to be used for safety-related ITS services.

It is clear that Urban Rail systems and ITS coexist geographically. This raises the issue of coexistence in the 5 915 MHz to 5 925 MHz band. Noting that this band is reserved for ITS use (ECC/DEC/(08)01) [i.1], any usage by Urban Rails would require conformance to the ITS specifications for usage in this band. Such conformance would also provide the opportunity to deploy ITS and Urban Rail cooperative traffic safety and traffic flow-regulating services.

5 Presentation of the system or technology

The functionalities as described in the present document will be implemented in one single system. The DCS system concept is therefore developed to provide a solution that is open for parallel communication sessions between trains and the infrastructure, and optionally between trains in the future, thus providing mechanisms that give the safety relevant applications the highest priority all the time.

A fast and versatile communication system platform is needed to support the increasing number of Railway mobile applications, including Safety, secure control and traffic management relevant applications.

The primary public objective is to provide urban rail and regional railways operators a system to control and manage the traffic on their own network. CBTC is a wireless Automatic Train Control (ATC) system, more flexible and cost efficient than traditional ATC.

6 Market information

6.1 Summary of application types

6.1.1 Overview

The connectivity required by the applications can be summarized as:

1) train-to-trackside (uplink) and trackside-to-train (downlink):
   - OBU to one TSU (point-to-point communication);
   - TSU to one OBU (point-to-point communication);
   - TSU to many OBUs; broadcast call;
   - TSU to selected OBUs; multicast and geocast (Group Call communication).
2) inter-train (optionally including multi-hop routing involving several trains):
   - between co-directional trains;
   - between trains in the opposite direction of travel.

6.1.2 Examples of applications

The applications shown in figure 1 are neither exhaustive nor complete and continue to expand as Urban Rail systemsincluding regional railways evolve. However, the figure gives an indication of the types of applications:

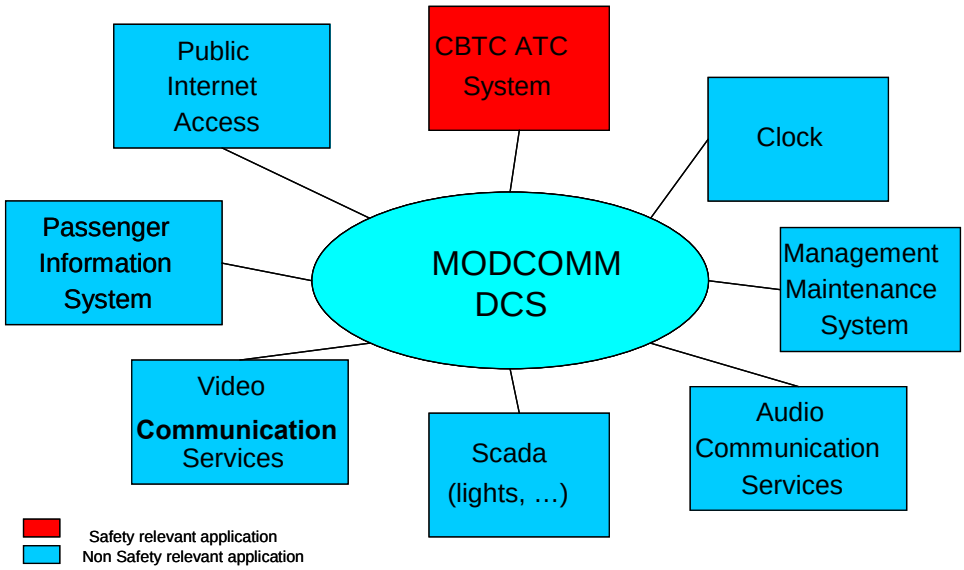

Figure 1: Safety-relevant and non-safety relevant applications

The safety relevant, secure control, traffic management, and video applications are the driving interest from both train manufacturers, mass transit and regional railway operators, and also public authorities.

Railway safety and efficient secure control are global concerns, and the development in many countries shows that a new technology is needed to make the grade. The European Railway research has invested a lot of work in DCS systems, as demonstrated by the results of MODURBAN IP project [i.8], [i.9] and [i.10].

Due to financial reasons and in order not to overload trains with different communication systems, the data communication system (DCS) should allow for both safety relevant plus secure control and traffic management applications and non-safety relevant applications, which are based trackside-to-train and/or trainside-to-track communications. Some of them should be extended in the future to train-to-train communication.

The distinction between safety relevant and non-safety relevant applications is crucial, but together they give a ROI rate that safety relevant applications are unable to provide alone. Therefore both classes of applications, at least to some extent, contributes to railway safety.

6.2 Market size and value

By its very nature, every CBTC system is totally dependent on quality radio communication to operate.

It is also now observed that an overwhelming majority of metro properties are calling on CBTC both for their new lines and for renewing their existing systems: this represents an estimated 30 lines worldwide being equipped with CBTC each year; with an estimated 20 % - 25 % of the projects located in Europe.

The typical impact can be measured in several ways, market value (1 000 M€), number of passengers benefitting (20 million per day), or number of people impacted by each incident (several 10 thousands) which occurs from an interruption of service resulting from radiocommunication failure.

As for Europe (EU27), about 70 projects have been already recorded on operators' side for operational CBTC service:

- 18 until 2015
- 12 between 2016 and 2020
- additionally around 40 beyond 2020

Based on these 70 projects and an assumption of 30 km and 50 trains per project, each of them would involve 250 radios in full traffic conditions. This leads to a total of 17 500 transmitters either fixed and/or mobile at the end of the current planned deployment.

However other projects not yet identified can be expected which would largely increase the above figure, knowing that there are currently 152 metro lines in operation (EU27). See: http://www.urbanrail.net/eu/eurom et.htm and figure 2:

Figure 2: Urban rail in Europe (source: http://www.urbanrail.net/eu/eurom et.htm)

6.3 Expected timing for Railway DCS market in Europe

It is intended to place new commercial CBTC products on the market, i.e. built into trains, by 2014-2015. Under the assumption that it would take approximately two years for planning and preparing the incorporation of the new standard into trains, a final frequency decision from CEPT/ECC is required before the end of 2014 to support adequate and secure planning efforts.

6.4 Traffic evaluation

The functionality required of a high data rate communication system for next-generation DCS systems is that it supports a highly dynamic traffic environment, in a range of environments and weather conditions, and with communication ranges extending from tenths to several hundred meters, up to 1 kilometre. It needs to be capable of providing broadcast, multicast, geocast and point-to-point communications.

The communications traffic will be distributed over each important city of a country, with a user density heavily dependent on the scenario.

However, it is to note that:

- only one DCS transmitting device in a defined geographic area uses a frequency channel at the same time and uses listen-before-talk and transmitter power reduction in congestion situations;
- the frequency re-use distance depends on the DCS transmitter power and varies between 15 m to 1 000 m;
- the average conveyed DCS duty cycle can be assumed to be in the range of 10 % to 15 % for one transmitter.

7 Technical information

7.1 Detailed technical description

The European Railway research has invested a lot of work in DCS systems; see the results of MODURBAN IP project [i.8], [i.9] and [i.10].

7.2 Technical parameters and implications on spectrum

7.2.1 Status of technical parameters

7.2.1.1 Current ITU and European Common Allocations

Tables 1 and 2 show the excerpts of from ERC Report 25 [i.22] for the frequency ranges 5 850 MHz - 5 925 MHz and 5 925 MHz - 6 700 MHz respectively.

Table 1: Excerpt from ERC Report 25 [i.22] for 5 850 MHz - 5 925 MHz

RR Region 1 Allocation and RR footnotes applicable to CEPT	European Common Allocation	ECC/ERC harmonisation measure	Applications	Standard	Notes
5 850 MHz - 5 925 MHz					
FIXED	FIXED	ECC/REC/(06)04 [i.33]	BFWA	ETSI EN 302 502 [i.32]	Within the band 5 725 - 5 875 MHz
FIXED-SATELLITE (E/S)	FIXED-SATELLITE (E/S)		FSS Earth stations	ETSI EN 301 443 [i.37]	Priority for civil networks
MOBILE	MOBILE		ISM		Within the band 5 725 - 5 875 MHz
5.150 (see note)	5.150 (see note)	ECC/DEC/(08)01 [i.1] ECC/REC/(08)01 [i.19]	ITS	ETSI EN 302 571 [i.7]	Within the bands 5 875 - 5 925 MHz and 5 855 - 5 875 MHz
		ERC/REC 70-03 [i.17]	Non-Specific SRDs	ETSI EN 300 440 [i.34]	Within the band 5 725 - 5 875 MHz
		ERC/REC 70-03 [i.17]	Radiodetermination applications	ETSI EN 302 372 [i.35]	Within the band 4 500 - 7 000 MHz for TLPR application
NOTE: 5.150: "The following bands: … 5 725 - 5 875 MHz (centre frequency 5 800 MHz) are also designated for industrial, scientific and medical (ISM) applications. Radio communication services operating within these bands must accept harmful interference which may be caused by these applications. ISM equipment operating in these bands is subject to the provisions of No. 15.13" [i.30].					

Table 2: Excerpt from ERC Report 25 [i.22] for 5 925 MHz - 6 700 MHz

RR Region 1 Allocation and RR footnotes applicable to CEPT	European Common Allocation	ECC/ERC harmonisation measure	Applications	Standard	Notes
5 925 MHZ - 6 700 MHz					
FIXED 5.457 (see note 1)	FIXED	ERC/REC 14-02 [i.33]	Fixed	ETSI EN 302 217 [i.36]	Point-to-point
FIXED-SATELLITE (E/S) 5.457A (see note 2) 5.457B (see note 3)	FIXED-SATELLITE (E/S)		FSS Earth stations	ETSI EN 301 443 [i.37]	Priority for civil networks
MOBILE 5.457C (see note 4)	Earth exploration-satellite (passive)		Passive sensors (satellite)		For sea surface temperature, sea surface wind speed and soil moisture measurements
5.149 (see note 5)	5.149 (see note 5)	ERC/REC 70-03 [i.17] ECC/DEC/(11)02 [i.39]	Radiodetermination applications	ETSI EN 302 372 [i.35] ETSI EN 302 729 [i.40]	Within the band 4 500 MHz - 7 000 MHz for TLPR application. Within the band 6 000 MHZ - 8 500 MHz for LPR applications

RR Region 1 Allocation and RR footnotes applicable to CEPT	European Common Allocation	ECC/ERC harmonisation measure	Applications	Standard	Notes
5.440 (see note 6)	5.440 (see note 6)	ECC/DEC/(06)04 [i.33]	UWB applications	ETSI EN 302 065 [i.41] ETSI EN 302 500 [i.42]	Generic UWB
5.458	5.458		Radio astronomy		Spectral line observations. (e.g. methanol line), VLBI
NOTE 1: 5.457: "In Australia, Burkina Faso, Cote d'Ivoire, Mali and Nigeria, the allocation to the fixed service in the bands 6 440MHz - 6 520 MHz (HAPS-to-ground direction) and 6 560 MHz - 6 640 MHz (ground-to-HAPS direction) may also be used by gateway links for high-altitude platform stations (HAPS) within the territory of these countries. Such use is limited to operation in HAPS gateway links and shall not cause harmful interference to, and shall not claim protection from, existing services, and shall be in compliance with Resolution **150 (WRC-12)**. Existing services shall not be constrained in future development by HAPS gateway links. The use of HAPS gateway links in these bands requires explicit agreement with other administrations whose territories are located within 1 000 kilometres from the border of an administration intending to use the HAPS gateway links. (WRC-12)" [i.30].					
NOTE 2: 5.457A: "In the bands 5 925 MHz - 6 425 MHz and 14 GHz - 14,5 GHz, earth stations located on board vessels may communicate with space stations of the fixed-satellite service. Such use shall be in accordance with Resolution **902 (WRC-03)**. (WRC-03)" [i.30].					
NOTE 3: 5.457B: "In the bands 5 925 MHz - 6 425 MHz and 14 GHz - 14,5 GHz, earth stations located on board vessels may operate with the characteristics and under the conditions contained in Resolution **902 (WRC-03)** in Algeria, Saudi Arabia, Bahrain, Comoros, Djibouti, Egypt, United Arab Emirates, Jordan, Kuwait, Libya, Morocco, Mauritania, Oman, Qatar, the Syrian Arab Republic, Sudan, South Sudan, Tunisia and Yemen, in the maritime mobile-satellite service on a secondary basis. Such use shall be in accordance with Resolution **902 (WRC-03)**. (WRC-12)" [i.30].					
NOTE 4: 5.457C: "In Region 2 (except Brazil, Cuba, French overseas departments and communities, Guatemala, Paraguay, Uruguay and Venezuela), the band 5 925 MHz - 6 700 MHz may be used for aeronautical mobile telemetry for flight testing by aircraft stations (see No. **1.83**). Such use shall be in accordance with Resolution **416 (WRC-07)** and shall not cause harmful interference to, nor claim protection from, the fixed-satellite and fixed services. Any such use does not preclude the use of this band by other mobile service applications or by other services to which this band is allocated on a co-primary basis and does not establish priority in the Radio Regulations. (WRC-07)" [i.30].					
NOTE 5: 5.149: "In making assignments to stations of other services to which the bands: …6 650 MHz - 6 675.2 MHz … are allocated, administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference. Emissions from spaceborne or airborne stations can be particularly serious sources of interference to the radio astronomy service (see Nos. **4.5** and **4.6** and Article **29**). (WRC-07)" [i.30].					
NOTE 6: 5.440: "The standard frequency and time signal-satellite service may be authorized to use the frequency 4 202 MHz for space-to-Earth transmissions and the frequency 6 427 MHz for Earth-to-space transmissions. Such transmissions shall be confined within the limits of 2 MHz of these frequencies, subject to agreement obtained under No. **9.21**" [i.30].					
NOTE 7: 5.458: "In the band 6 425 MHz - 7 075 MHz, passive microwave sensor measurements are carried out over the oceans. In the band 7 075 MHz - 7 250 MHz, passive microwave sensor measurements are carried out. Administrations should bear in mind the needs of the Earth exploration-satellite (passive) and space research (passive) services in their future planning of the bands 6 425 MHz - 7 075 MHz and 7 075-7 250 MHz" [i.30].					

In ITU-R, there are some Recommendations and Reports related to the 5 GHz band, mostly reflecting current RTTT DSRC allocations in Europe and Japan [i.23] and advanced ITS [i.24].

7.2.1.2 Sharing and compatibility studies (if any) already available

The ANFR has studied the compatibility between metro systems operating at 5 915 - 5 935 MHz and ITS at 5 875 - 5 915 MHz as well as the compatibility between metro systems and ITS sharing the band 5 915 - 5 925 MHz band [i.27].

7.2.1.3 Sharing and compatibility issues still to be considered

Coexistence studies with existing radio services in the upper 5 GHz range are needed; tables 1 and 2 as well as figure 5 can be used to determine which studies should be done. In addition the work on the EC Mandate on the 5 GHz WAS/RLAN extension band [i.28] and [i.29] should be considered.

For non-safety related services, sharing bandwidth with ITS is to be considered as shown in figure 5.

A number of study items are anticipated to be done within ECC:

- coexistence with SATCOM uplinks (5,925 GHz to 6,425 GHz), even if the lowest part of the band seems not to be used much in Europe;
- coexistence with European DSRC (5,795 GHz to 5,805 GHz), which has a poor selectivity because badges should be RF-energised;
- coexistence with ITS (5,855 - 5,925 GHz).
- Coexistence with road safety and traffic management related RTTT/ITS services (in both V2R and V2V) need studies within ECC.

7.2.2 Transmitter parameters

7.2.2.1 Transmitter Output Power/Radiated Power

The transmission mask of the system is given in figure 3:

EIRP max is 900 mW = 29,94 dBm. Antenna gain is about 17 dBi.

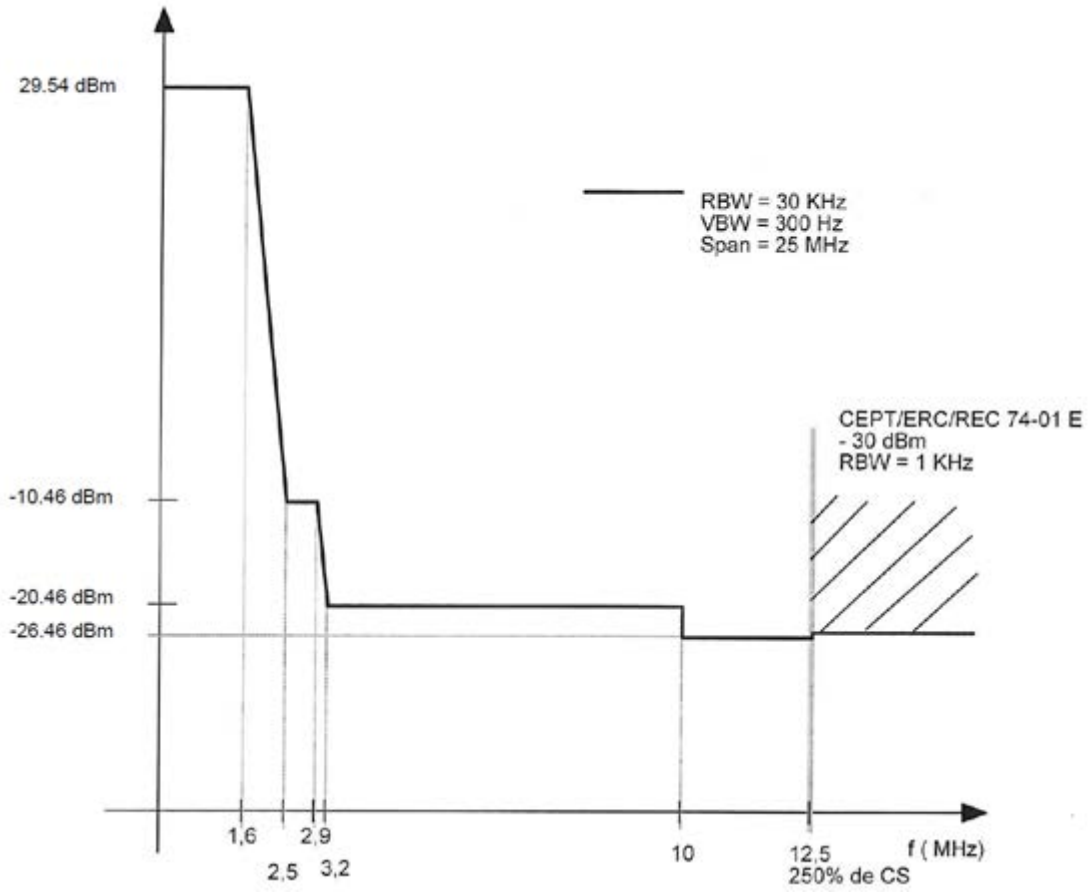

Figure 3: Spectrum mask of the system

The required power level (EIRP) range is from 3 dBm to 33 dBm to achieve communication distances of up to 1 000 m. The related maximum power spectral density (EIRP) is 23 dBm/MHz.

It should be noted that a number of trackside-to-train applications will require a much shorter communications distance than 1 000 m, and therefore lower power levels than 33 dBm are involved on average. If it is considered an average range of 700 m in rural areas, one needs an EIRP not exceeding 20 dBm.

During the introduction phase, DCS will apply TPC and reduce the transmission power to the level needed for reliable communication. This is a good way to ensure efficient channel reuse and the link quality.

If enforced, Transmitter Power Control with a dynamic range of 30 Db if the EIRP should be above 27 dBm.

The typical communication range is expected to be up to 1 000 m for rural areas. In suburban and urban areas, the communication range is usually lower, except in tunnels, where the range can be better, due to waveguiding effects in the 5 GHz band.

TSUs will provide a communication zone. The required size of the zone depends on the services, which are provided by the TSU, and on the environment. A typical value for rural areas is 700 m and for urban areas 400 m.

7.2.2.1a Antenna Characteristics

The antenna diagram according to Recommendation ITU-R F.699 [i.25] is shown in figure 4. It uses vertical polarization.

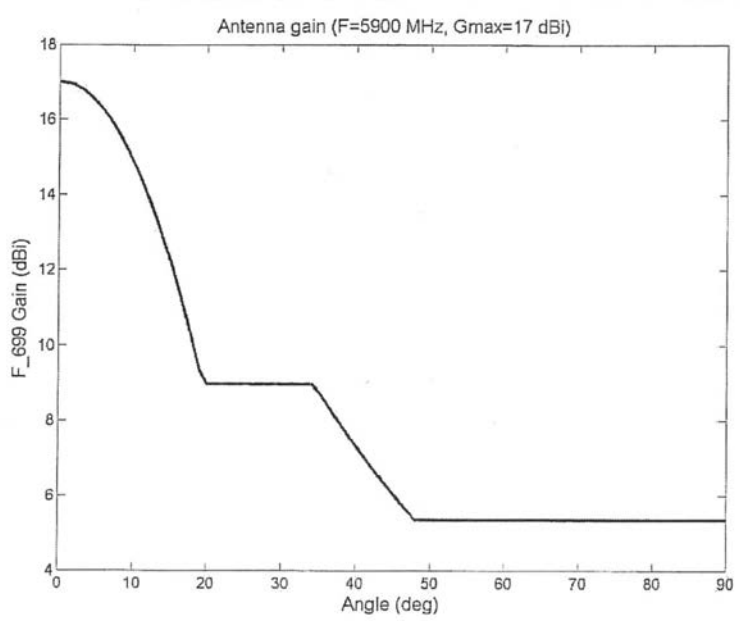

Figure 4: The antenna diagram according to Recommendation ITU-R F.699 [i.25]

For the communication between vehicles and TSUs the required transmitted power can be asymmetric concerning uplink and downlink communications, because TSU can be deployed with more directive antennas. This means that the average interference contribution from TSUs will be significantly lower than the EIRP value on its own would indicate. The EIRP max is 29,54 dBm for TSU and vehicles. In vehicles, standard horn antenna are used (average gain: 17 dBi) TSU uses antenna patch. Two antennas are installed for one TSU. They are installed "back to back" to have a linear coverage. TSU can also use one antenna patch because of the tunnel constraints.

7.2.2.2 Operating Frequency

The proposed frequency bands are given in clause 8.1.

7.2.2.3 Bandwidth

The occupied bandwidth (99 % of the total mean power) is less than 3 MHz.

Typical channel bandwidths considered are 5 MHz (for CBTC) to 10 MHz wide channels.

See also clause 8.2.

7.2.2.4 Unwanted emissions

See clause 7.2.2.1.

The unwanted emissions in the spurious domain are defined by CEPT/ERC Recommendation 74-01 [i.26]. The system is mobile, thus the limit of the mean power in the spurious domain is -30 dBm (reference number 2.1.1 in [i.26]).

7.2.3 Receiver parameters

The receivers parameters for the system are given in table 3:

Table 3: Receiver parameters

parameter	value
sensitivity	-95 dBm in 3 MHz
selectivity	rejection 50 dBc for 5 MHz channel spacing
intermodulation	no data for the moment
co-channel rejection	no data
blocking	-10 dBm

7.2.4 Channel access parameters

Only one DCS transmitting device in a defined geographic area uses a frequency channel at the same time and uses listen-before-talk and transmitter power reduction in congestion situations.

The average conveyed DCS duty cycle can be assumed to be in the range of 10 % to 15 % for one transmitter.

7.3 Information on relevant standard(s)

Europe approved the use of microwave communication with the RTTT DSRC systems at 5,8 GHz, and is now working towards more capable microwave solutions enabling ITS mobile communications both for low latency applications, and for sophisticated networking applications using Internet protocol as well as other protocols.

For ITS, which have concomitant needs, basic protocols for high-reliability safety related services have been developed. As results in Europe, ETSI published EN 302 663 [i.5].

For railway, and especially urban rail systems, there is not yet any standard of the same kind in Europe.

ETSI intends to develop standards necessary for the considered frequency band use of safety relevant applications, secure control, and video applications. These bands are expected to cover the technical operational specifications and measurement requirements for Urban Rail devices.

Another standard, ETSI EN 302 665 [i.4], does not directly cover spectrum issues but might be regarded as relevant as regards the access layer, which addresses a physical layer connecting to the communication medium (including at 5,9 GHz), and a layer manager directly managing the physical layer and a data link layer. This standard follows the CALM initiative at ISO through its TC204 WG16 group, which issued IS0 21215 [i.6], as an adaptation for the M5 radio communication using IEEE 802.11p [i.3]. M5 stands for "Medium 5 GHz". Note that a parallel initiative also started in February 2011 in IEC TechnicalGroup9, WorkGroup43, SGT5 "Board to Ground" (IEC 61375-2-6 [i.16]).

8 Radio spectrum request and justification

A wide range of different types of safety and traffic management relevant communication systems makes achieving safety more complex while increasing costs and limiting efficiency. Therefore usage of standardised components is preferred.

Thus, a high degree of harmonisation of frequencies on the global level is necessary, since needs for these applications exist throughout the world, and since trackside and train radio equipments are marketed in the global marketplace.

8.1 Spectrum

Microwave systems in the 5 GHz range can offer communications with a high data rate, ranges up to 1 000 m, low weather-dependence, and global compatibility and interoperability. This band is also known as offering a good propagation in a difficult environmental condition such as that encountered in small tunnel and masking trains.

Spectrum on a European-wide basis is needed as railway systems should enable communications between trains and the infrastructure, in an environment where the train marketplace is global and manufacturers providing train models on a global basis with the minimum of variation to meet national requirements.

Figure 5 presents the preferred spectrum for Urban Rail radio communication systems.

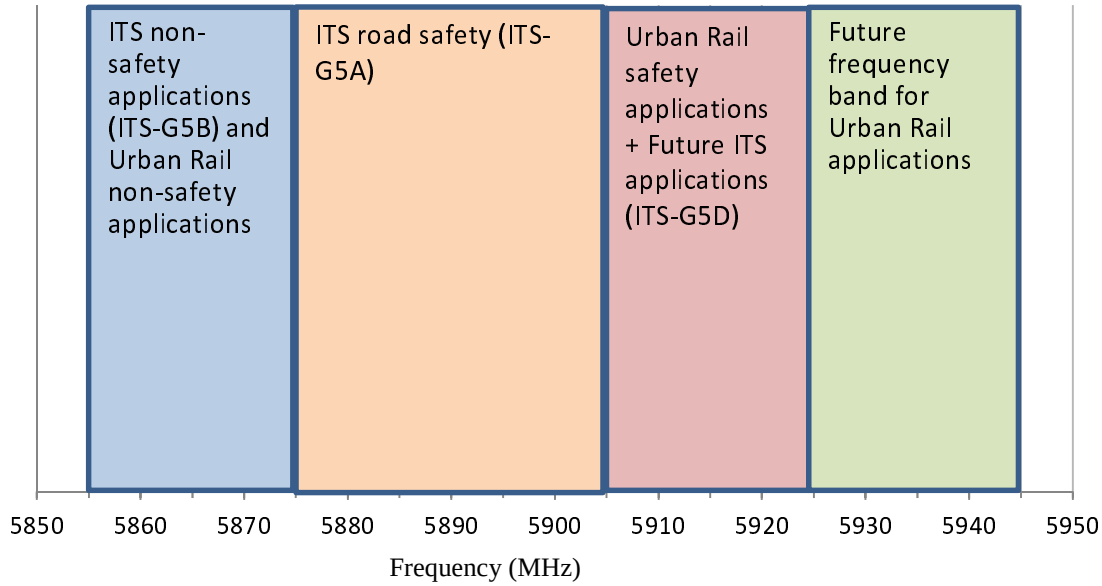

Figure 5: Urban Rail spectrum proposal including current and possible future ITS designations

It is proposed to designate 20 MHz of spectrum for CBTC and safety relevant critical applications as described in figure 5a, preferably within the frequency range from 5,905 GHz to 5,925 GHz.

Urban Rail Communications

Client services	Link		safety communication	Application priority	Data rate per link (in Kbps)	Number of links per line		Cumulative data rate (in KBps)	
	train	ground				nominal	maximum	nominal	maximum
ATC System									
	Car Controler	Zone Controler	Yes	High	10Kbps	40 trains	100 trains	400	1000
	Car Controler	Central controler	Yes	High	20Kbps	40 trains	100 trains	800	20000
	Car Controler	Central controler	Yes	High	20Kbps	40 trains	100 trains	800	20000
Maintenance Management System									
	Train Information	Central Management	No	Low	0.5Kbp	40 trains	100 trains	20	50
	Car Controler	Central Management	No	Low	0.5Kbp	40 trains	100 trains	20	50
Video Transmission									
	Train Video	Central Controler	No	Low	2000Kbps	2 video flows	4 video flows	4000	8000
Audio Video									
	Audio in Train	Central Controler	No	Low	64Kbps	20 calls	200 calls	1280	12800
Passager Information System									
	Train Information	Central Controler	No	Low	10Kbps	40 trains	100 trains	400	10000
Other									
	Train	Central Controler	No	Low	10Kbps	40 trains	100 trains	400	10000

Figure 5a

It is also proposed to designate 20 MHz of spectrum, i.e. 5,855 GHz to 5,875 GHz, for non-safety related urban rail applications (secure control, railway traffic management and video-surveillance). To consider the sharing issue and use of such spectrum, it is proposed to consider urban rail applications in the ITS scope.

It also requested to consider in a future review of the proposed ECC Decision the designation of 5,925 GHz to 5,945 GHz for future Urban Rail applications.

It is proposed that DFS and TPC mechanisms will not be implemented inside potentially reserved channels above 5,905 GHz.

Dedicated channel spacing is not proposed to be regulated. Typical channel bandwidths considered are 5 MHz (for CBTC) to 10 MHz wide channels. The exact channelization and frequency usage will be detailed later. Indeed, for efficiency reasons, users are requested to implement a prioritization concept (safety and other applications as well as control) in their protocol stack.

The required power level (EIRP) range is from 3 dBm to 33 dBm to achieve communication distances of up to 1 000 m. The related maximum power spectral density (EIRP) is 23 dBm/MHz.

If enforced, Transmitter Power Control with a dynamic range of 30 Db if the EIRP should be above 27 dBm.

8.2 Technical justification for bandwidth

If a 200 Bytes - 1 000 Bytes CBTC packet content is assumed for each train (100 Bytes - 500 Bytes each direction) per second, then the next step is to assume the quantity of trains that need to be controlled. The worst case scenario is usually not along the main line, but in a train yard/depot. In this scenario, dozens of trains and maintenance vehicles can be stationary, yet still in full CBTC communication with the wayside controller. In the same position, basic data should be downloaded and uploaded, e.g. with 500 Byte packets. An assumption of 50 communicating mobile units that communicate each second leads to:

500 Bytes/packet × 2 directions/radio link × 8 bits/Byte × 50 packets/second = 400 kbps.

The supported protocol - not specified here - is expected to provide efficiency under 20 %, including duty cycle, gaps, and access mechanism. This means a need for a rough rate of 2 000 kbps at least.

It is reasonable to assume that a phase-modulated radio will be used, and that some protection will be expected from the coding and modulation process. A minimum of 6 Db looks reasonable. Assuming a modulation with the minimal spectral efficiency of QPSK leads to an RF Baud rate of 4 Mbaud (2 bits per symbol from 4 × 2 Mbps).

So the nominal bandwidth, with a QPSK signal changing at 4 Mbaud, is about 4 MHz. Allowing a guard band between channels, 5 MHz is the minimum channel spacing.

8.3 Technical justification for power levels

A number of macroscopic propagation models have been proposed for dimensioning wireless links.

Formulas define EIRP as a n power of the distance range, with n depending on the electromagnetic environment:

- n = 2 in LOS conditions (slope 20 Db/decade).
- n = 4 in NLOS conditions (slope 40 Db/decade).
- n (and slope) can be much lower in waveguiding conditions inside a tunnel.

These formulas include other variables as parameters , such as frequency, antenna gain, bit rate.

In any case, the greater the distance ranges, the greater the transmit power (EIRP) needed; see table 1.

Table 4 was obtained assuming QPSK with mitigated values of the slopes and of the parameters. The following power levels should be considered for compatibility investigations:

Table 4: Ranges corresponding with various transmitter powers

Range (m)	1 000	500	400	300	200	100	50
TP (dBm)	33	25	22	19	14	6	3 (see note 1)
NOTE 1: If TPC is applied, the minimum power level is 3 dBm. NOTE 2: These figures assume QPSK with mitigated values of the slopes and of the parameters.							

9 Regulations

9.1 Current regulations

Tables 1 and 2 in clause 7.2.1 show the excerpts of from ERC Report 25 [i.22] for the frequency ranges 5 850 MHz - 5 925 MHz and 5 925 MHz - 6 700 MHz respectively.

The current situation regarding the ITS-G5A, B, C, D and CEN DSRC frequency bands is shown in figure 6.

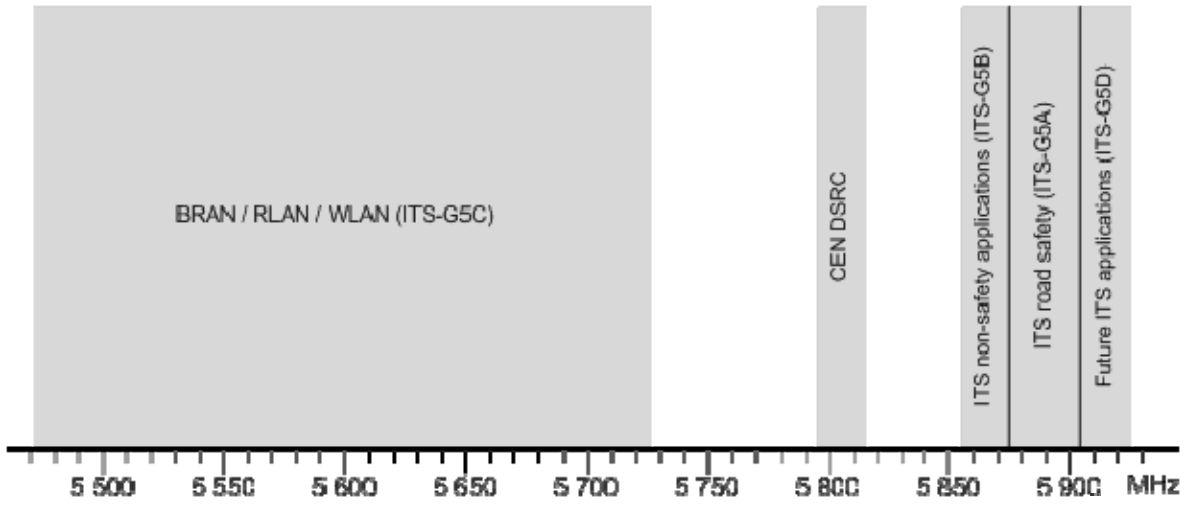

Figure 6: ITS-G5A, B, C, D and CEN DSRC frequency bands [i.1]

9.1.1 WAS/RLAN: 5,470 GHz to 5,725 GHz

The spectrum range from 5,470 GHz to 5,725 GHz is designated for WAS/RLAN under the regulatory regime as presented in ECC DEC(04)08 [i.2] and EC Decision 2005/513/EC [i.20], open for outdoor usage. Due to the required DFS procedure, the applicability of this frequency band for railway applications is limited to communications between Track-Side Units and trains.

9.1.2 TTT: 5,795 GHz to 5,815 GHz

CEPT/ERC Recommendation 70-03 Annex 5 [i.17] includes the designation of the following frequency bands to transport and traffic telematics (road, rail water and air), traffic management, and navigation and mobility management:

a) from 5,795 GHz to 5,805 GHz; and

b) from 5,805 GHz to 5,815 GHz.

An individual license may be required in these frequency bands. For both these bands, some countries have restrictions, such as "for road toll systems only", on use. Because these bands are in the frequency band ranging from 5,725 GHz to 5,875 GHz which is also designated for ISM, sufficient predictable sharing conditions as required for railway safety and non-safety relevant services are not available.

EC Decision 2013/752/EU [i.21] provides a set of usage conditions for 5,795 GHz - 5,805 GHz for road tolling applications.

9.1.3 ITS: 5,855 GHz to 5,875 GHz

ECC Recommendation (08)01 [i.19] recommends the designation of the frequency band 5,855 GHz to 5,875 GHz for ITS non-safety applications.

9.1.4 ITS: 5,875 GHz to 5,905 GHz and 5,905 GHz to 5,925 GHz

The current situation regarding designation of the frequency band 5,875 GHz to 5,905 GHz for safety-related applications of ITS results from ECC Decision [i.1] and EC Decision [i.18]. ECC Decision [i.1] also decides "that CEPT administrations shall consider within a future review of this Decision the designation of the frequency sub-band 5 905 MHz - 5 925 MHz for an extension of ITS spectrum noting that protection of ITS can not be ensured in this band".

9.1.5 Information on current frequency agreements for rail in Europe

Pioneer systems have been deployed in some countries, e.g. France, UK and Spain, in bands also designated for ISM applications (i.e. those bands with center frequencies 2,45 GHz; 5,8 GHz) or in a nationally granted specific band, e.g. 5,915 GHz to 5,935 GHz in France.

A few preliminary spectrum licenses have been granted by the French national Authority (ART, now ARCEP):

- to SNCF for freight trains: 5,915 GHz to 5,935 GHz in 2004, for 10 years in the whole of France;
- to RATP for the Paris subway: 5,915 GHz to 5,935 GHz in 2004, for 10 years in Paris and suburbs, to be coordinated with SNCF;
- to SYTRAL for the Lyon subway: 5,915 GHz to 5,935 GHz in 2010, till end of 2013;
- in Copenhagen: 5,925 GHz to 5,935 GHz in 2010, till end of 2025;
- in Helsinki: 5,925 GHz to 5,960 GHz in 2010.

ARCEP defined a maximum EIRP of 30 dBm outside and inside tunnels.

9.2 Proposed regulation and justification

The spectrum arrangement given in clause 8.1 is proposed for Urban Rail systems.

The required power level (EIRP) range is from 3 dBm to 33 dBm to achieve communication distances of up to 1 000 m. The related maximum power spectral density (EIRP) is 23 dBm/MHz.

The format of the ECC Decision (08)01 for ITS [i.18] may be reused for a new ECC Decision on Urban Rail systems.

9.2.1 Requested licensing conditions

The spectrum for CBTC services should be individually licensed.

Important conditions to note are:

- it is a public concern to improve urban rail systems safety and traffic management, and as such, it is politically prioritized; see mandate M/486 [i.12] for further background;
- there are practical problems with licensing in a global market;
- urban rail video services are expected to have a slow take-off if there are costly licensing policies.

History

Document history		
V1.1.1	October 2014	Publication