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Electromagnetic compatibility and Radio spectrum Matters (ERM); System Reference document (SRdoc); Technical characteristics for pan European harmonized communications equipment operating in the 5,855 GHz to 5,925 GHz range intended for road safety and traffic management, and for non-safety related ITS applications

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Foreword

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

Introduction

The present document includes necessary information to support the co-operation under the MoU between ETSI and the Electronic Communications Committee (ECC) of the European Conference of Post and Telecommunications Administrations (CEPT).

In the present document the existing frequency allocation for Intelligent Transport Systems (ITS) including the out-of-band spectrum mask will be reviewed. This review will include a detailed analyses of the interference potential of the ITS systems operating in the 5 GHz band towards potential victim services.

1 Scope

The present document describes the updated spectrum usage requirements for equipment related to:

- roadside/infrastructure to vehicle communications (RVC);
- inter-vehicle communications (IVC);
- restricted portable devices to vehicle communications;

with the main focus onto the out-of-band spectrum mask in the band between 5 725 MHz to 5 965 MHz in order to allow for an efficient system implementation.

It includes necessary information to support the co-operation between ETSI and the Electronic Communications Committee (ECC) of the European Conference of Post and Telecommunications Administrations (CEPT), including:

- Market information in annex A.
- Technical information in annex B.
- Coexistence information in annexes C and D.

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

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

2.1 Normative references

The following referenced documents are necessary for the application of the present document.

Not applicable.

2.2 Informative references

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] CEPT 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.2] FCC Rules and Regulations, (August 3, 2004): "Regulations governing the licensing and use of frequencies in the 5850 – 5925 MHz band for Dedicated Short Range Communications Service".

[i.3] Car-2-Car Communication Consortium (Press Release of 10 October 2012): "European vehicle manufacturers working hand in hand on deployment of cooperative Intelligent Transport Systems and Services (C-ITS)".

NOTE: Available at: https://www.car-2-car.org/car2car08/index.php?id=20.

[i.4] ETSI EN 300 674: "ElectroMagnetic Compatibility and Radio Spectrum Matters (ERM); Road Transport and Traffic Telematics (RTTT); Technical characteristics and test methods for Dedicated Short Range Communication (DSRC) transmission equipment (500 kbit/s/250 kbit/s) operating in the 5,8 GHz Industrial, Scientific and Medical (ISM) band".

[i.5] Commission Decision 2008/671/EC of 5 August 2008 on the harmonised use of radio spectrum in the 5 875-5 905 MHz frequency band for safety-related applications of Intelligent Transport Systems (ITS).

[i.6] ETSI EN 302 571 (V1.2.1): "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.7] ECC/DEC/(08)01: "ECC Decision of 14 March 2008 on the harmonised use of the 5875-5925 MHz frequency band for Intelligent Transport Systems (ITS)".

[i.8] ECC/REC/(08)01: "ECC Recommendation (08)01 on the use of the band 5855-5875 MHz for Intelligent Transport Systems (ITS)".

[i.9] ECC Report 101: "Compatibility studies in the band 5855- 5925 MHz between Intelligent Transport Systems (ITS) and other systems", Bern, February 2007.

[i.10] ECC Report 109: "The aggregate impact from the proposed new systems (ITS, BBDR and BFWA) in the 5725-5925 MHz band on the other services/systems currently operating in this band", Budapest, September 2007.

[i.11] IEEE 802.11j: "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 7: 4.9 GHz-5 GHz Operation in Japan".

[i.12] IEEE 802.11a: "Information Technology – Telecommunications and Information Exchange Between Systems – LAN/MAN – Specific Requirements".

[i.13] IEEE 802.11-2012: "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.14] IEEE 802.11h: "Standard for IT – Telecommunications and information exchange between systems – LAN/MAN – Specific requirements Part 11: Wireless MAC and PHY Specifications – Spectrum and Transmit Power Management Extensions in the 5 GHz Band in Europe".

[i.15] SRDMG(13)Info3: "Implementation status ECC/DEC/(08)01 at the end of 2012".

[i.16] ETSI TR 101 607: "Intelligent Transport Systems (ITS); Cooperative ITS (C-ITS); Release 1".

[i.17] 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.18] ETSI EN 302 665: "Intelligent Transport Systems (ITS); Communications Architecture".

[i.19] Project: SimTD: Sichere Intelligente Mobilität: Testfeld Deutschland.

NOTE: Available at http://www.simtd.de/.

[i.20] European Commissions Mandate M/453: "Standardisation Mandate addressed to CEN, CENELEC and ETSI in the field of information and communication technologies to support the interoperability of Co-operative Systems for Intelligent Transport in the European Community", Brussels, October 2009.

[i.21] CEPT/ERC Report 25: "The European Table of Frequency Allocations and Utilisations Covering the Frequency Range 9 kHz to 275 GHz".

[i.22] Recommendation ITU-R F.1613: "Operational and deployment requirements for fixed wireless access systems in the fixed service in Region 3 to ensure the protection of systems in the Earth exploration-satellite service (active) and the space research service (active) in the band 5 250-5 350 MHz".

[i.23] Recommendation ITU-R M.1638: "Characteristics of and protection criteria for sharing studies for radiolocation, aeronautical radionavigation and meteorological radars operating in the frequency bands between 5 250 and 5 850 MHz".

[i.24] Recommendation ITU-R SA.1632: "Sharing in the band 5 250-5 350 MHz between the Earth exploration-satellite service (active) and wireless access systems (including radio local area networks) in the mobile service".

[i.25] CEN EN 12795: "Road transport and traffic telematics – Dedicated Short Range, Communication (DSRC) – DSRC data link layer: medium access and logical link control".

[i.26] ERC Rec 70-03: "Relating to the use od Short Range Devices (SRD)", Tromsø 1997, amended October 2013.

[i.27] CEN EN 13372: "Road transport and traffic telematics – Dedicated Short Range Communication (DSRC) – Profiles for RTTT applications".

[i.28] CEN EN 12253: "CEN EN 12253: "Road transport and traffic telematics – Dedicated Short Range Communication (DSRC) – Physical layer using microwave at 5,8 GHz".

[i.29] ETSI TR 102 654: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Road Transport and Traffic Telematics (RTTT); Co-location and Co-existence Considerations regarding Dedicated Short Range Communication (DSRC) transmission equipment and Intelligent Transport Systems (ITS) operating in the 5 GHz frequency range and other potential sources of interference".

[i.30] ETSI TR 102 960: "Intelligent Transport Systems (ITS); Mitigation techniques to avoid interference between European CEN Dedicated Short Range Communication (RTTT DSRC) equipment and Intelligent Transport Systems (ITS) operating in the 5 GHz frequency range Evaluation of mitigation methods and techniques".

[i.31] Recommendation ITU-R SM.329: "Unwanted emissions in the spurious domain".

[i.32] Recommendation ITU-R SM.1539: "Variation of the boundary between the out-of-band and spurious domains required for the application of Recommendations ITU-R SM.1541 and ITU-R SM.329".

3 Definitions, symbols and abbreviations

3.1 Definitions

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

inter-vehicle communications: generic expression for bi-directional communications between vehicles

NOTE: May include multi-hop routing involving several vehicles.

On-board unit: radio, transmitter and receiver, installed in a vehicle

NOTE: A portable user device brought into the vehicle and connected to the vehicle's electronic system will also fall under this definition.

Pedestrian-to-vehicle communications: communications between a mobile or portable user device and a vehicle

portable unit: pedestrian device, e.g. a portable user device that can send and receive vehicular safety messages

road-side unit: radio, transmitter and receiver, usually fixed as part of the road infrastructure installed along a road, e.g. on gantries above the lane or at poles beside the lane

NOTE: Can be a single RSU in a stand-alone fashion or a group of RSUs connected to infrastructure.

Roadside-to-vehicle communications: communication between a RSU and a mobile ITS station, also referred to as downlink communications

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

NOTE: May include multi-hop routing involving several vehicles, may allow for Internet access, may be based on handover between adjacent roadside units.

Road Transport and Traffic Telematic (RTTT): Transport and traffic telematics systems for the dedicated use in road environments

Transport and Traffic Telematic (TTT): systems in which information and communication technologies are applied in the field of transport (depending on technical restrictions for road rail, water and air), traffic management, navigation and mobility management, as well as for interfaces with other modes of transport including communication in vehicles between vehicles (e.g. car-to-car), and between vehicles and fixed locations (e.g. car-to-infrastructure).

NOTE: In the actual regulatory discussion and documents RTTT is being replaced with TTT, see ERC REC 70-03 [i.26].

Vehicle-to-roadside communications: communication between a mobile ITS station and an RSU, also referred to as uplink communications

3.2 Symbols

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

P_e	received power in dBm
P_s	transmit power in dBm
G_s	transmit antenna gain in dBi
G_e	receive antenna gain in dBi
L	path loss in dB
L_0	path loss in dB up to the breakpoint
d	distance
d_0	breakpoint
λ	carrier wave length
r	radius of first Fresnel zone
n	path loss coefficient

3.3 Abbreviations

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

ABS	Antilock Braking system
ACC	Automotive Cruise Control
BER	Bit error ratio
BPSK	Binary Phase shift Keying
BSA	Basic set of applications
BW	Bandwidth
C2C-CC	Car-to-Car Communication Consortium
CALM M5	CALM for the 5 GHz Microwave range
CALM	Continuous Air interface Long and Medium range
CAM	Cooperative awareness message
CEN	European Committee for Standardization
CEPT	European Conference of Postal and Telecommunications Administrations
dBm	Power in decibel relative to 1 mW

DCC	Decentralized Congestion Control
DENM	Decentralized Environmental Notification Message
DFS	Dynamic Frequency Selection
DSRC	Dedicated Short Range Communication
e.i.r.p.	equivalent isotropically radiated power
EC	European Commission
ECA	European Common Allocation
ECC	Electronic Communication Committee
EIRP	Equivalent Isotropically Radiated power
EN	European Norm
ERC	European Radiocommunications Committee
EU	European Union
FCC	Federal Communication Commission
FIXED	no abbreviations
FSS	Fixed Satellite System
GI	Guard Interval
GSO	Geostationary Satellite Orbit
IEEE	Institution of Electrical and Electronic Engineers
Ipv6	Internet Protocol version 6
ISM	Industrial, Scientific and Medical
ISO	International Standards Organization
ITS	Intelligent Transport Systems
ITS-G	5,9 GHz Cooperative ITS system
ITU-R	International Telecommunication Union – Radio
IVC	Inter-Vehicle Communications
LBT	Listen-Before-Talk
LHCP	Left Hand Circular Polarization
MAC	Medium Access Control
MSS	Mobile Satellite station
OBU	On-Board Unit
OEM	Original Equipment Manufacturer
PHY	Physical Layer
QPSK	Quadrature Phased Shift Keying
R&TTE	Radio Equipment & Telecommunications Terminal Equipment
R2V	Roadside-to-Vehicle
RF	Radio Frequency
RLAN	Radio Local Area Network
RR	Radio resource
RSU	Road-Side Unit
RTTT	Road Transport and Traffic Telematics
RVC	Roadside-Vehicle Communications
RX	Receiver
SRD	Short Range Device
TB	Technical Body
TBD	To be discussed
TC	Technical Committee
TPC	Transmit Power Control
TR	ETSI Technical Report
TS	Technical Specification
TTT	Transport and Traffic Telematic
TX	Transmitter
US	United States
USA	United States of America
V2R	Vehicle-to-Roadside
V2V	Vehicle-to-Vehicle
VTS	Vessel Traffic Service
WAS	Wireless Access System
WAVE	Wireless Access in Vehicular Environment

NOTE: Name of WLAN for Vehicular Environments technology in IEEE 802.11-1012 [i.13].

WLAN	Wireless Local Area Network

4 Executive summary

ECC Decision (08)01 and Commission Decision 2008/671/EC [i.5] identify the frequency band 5 875 MHz to 5 905 MHz on a non-exclusive basis for ITS road safety applications. ECC Decision (08)01 is currently implemented in 39 CEPT countries including all EU member states. TR 101 607 [i.16] includes the standards developed under the mandate 453 and was **agreed in early 2013 as the Release 1 for ITS in the spectrum 5 875 MHz to 5 905 MHz**. The objectives for a release process are:

- An organized process for standardization activity for cooperative ITS.
- Standardization based on agreed functionalities to be deployed by the stakeholders.
- The release process to be coordinated between the CEN and ETSI as far as possible.
- The functionalities and technologies (i.e. the features) to be subject to a consultation process with stakeholder deploying the cooperative ITS.

Release 1 is basically the "minimum set of standards" for interoperability provided in accordance with M/453 [i.20]. These standards are intended for the initial deployment of cooperative ITS and have been developed by ETSI and CEN. They include a basic set of ITS applications (BSA).

The application and facility layer standards cover the requirements deriving from the basic use cases identified by the involved stakeholders for the initial deployment. This includes agreed message sets as well as the higher layer data exchange protocols required for driver information and for dissemination of hazard warnings.

In addition a standard for a simplified point of interest notification service for electrical vehicles has been developed within ETSI and published.

The focus has been set on direct V2V communication, an access technology agnostic approach has been at all times followed, this guaranteeing the future validity of Release 1 standards.

The developed communication standards include the network and transport layers, GeoNetworking for ITS-G5 (GPS/Galileo positioning information is used) and Basic Transport Protocol being fully specified. The required standards for enabling Ipv6 based services to be deployed have been also developed and are part of the Release 1 document set.

Access and media standards for 5,9 GHz spectrum usage (profiling IEEE 802.11), multichannel operation, decentralized congestion control and coexistence of ITS and CEN-DSRC based services (road tolling/electronic fee collection) in the 5,8 GHz and 5,9 GHz bands have been covered by standards intended for this initial ITS release.

Furthermore, basic management and security standards as well as reference architecture standards, test specifications and reports from interoperability tests are included in Release 1.

Major car manufacturers recently signed a Memorandum of Understanding to signal their intentions to provide cooperative systems from 2015 on [i.3]. V2V communications will be integrated in the refined telematics platform of the vehicles and its applications will mainly evolve the three areas:

- advanced driver assistance increasing road safety;
- increasing traffic efficiency with traffic congestion control;
- user communications and information services (comfort and business applications).

The first implementation under Release 1 will most likely only use parts of the spectrum identified by ECC and EC.

The present document supports the review of the ITS regulation in the CEPT ECC and proposes reconsideration in particular on the following items:

1) Investigate the optimization of the existing spectrum mask for the deployment of ITS systems in the 5,9 GHz range with the main focus on the out-of-band emissions and the emissions in the spurious domain.

2) ECC is requested to consider exemption from individual licensing for all ITS stations, including the roadside-to-vehicle communications and portable ITS stations with restricted capabilities. In this context, it should be noted that in the ITS station concept, there is no difference in the functions between a vehicle-based station, a fixed installed station or a portable ITS station, i.e. all ITS stations can support all features and facilities.

3) Introduction of additional mitigation factors and methods for optimized coexistence.

5 Current regulations

5.1 Overview

The current regulation of the ITS G5 system is based on the EC decision 2008/671/EC of 5 August 2008 [i.5] as well as ECC/DEC/(08)01 [i.7] covering the ITS G5A channels from 5,875 GHz to 5,905 GHz and the ECC Recommendation ECC/REC/(08)01 [i.8] covering the ITS G5B channels from 5,855 GHz to 5,875 GHz. The essential requirements to fulfil the R&TTE Directive are covered in the Harmonized Standard EN 302 571 [i.6] for the band 5,855 GHz to 5,925 GHz. In the following clause the details of the existing regulation will be presented.

The ECC/DEC/(08)01 has been implemented by 38 CEPT administrations by the end of 2012 including all EU member states. While the authorization regime for inter-vehicle communications is clear, the process for roadside-to-vehicle, i.e. for fixed installed ITS stations, is not so clear and several administrations expressed the need to clarify the situation or see this under study. Two administrations use individual authorizations for roadside-to-vehicle communications while many others use license-exemption (see SRDMG(13)Info3 [i.15]). ECC Decision (08)01 is up for review in 2014.

5.2 Spectrum regulation for the ITS system in the band 5,855 GHz to 5,925 GHz

In table 1 the current regulatory limits for the total RF output power and the power spectral density as given in [i.5], [i.6] and [i.7] are depicted.

Table 1: Limits for total RF output power and Power Spectral Density at the highest power level based on [i.5], [i.6] and [i.7]

Frequency range (MHz)	RF output power limit (e.i.r.p.) (dBm)	Power spectral density limit (e.i.r.p.) (dBm/MHz)	Remark
5 855 to 5 875	33	23	ECC/REC/(08)01 [i.8]
5 875 to 5 905	33	23	ECC/DEC/(08)01 [i.7] and EC decision 2008/671/EC [i.5]
5 905 to 5 925	33	23	ECC/DEC/(08)01 [i.7]

The out-of-band spectrum requirements defined in Europe as part of the EU regulations in EU Decision 2008/671/EC [i.5], ECC/DEC/(08)01 [i.7] and ECC/REC/(08)01 [i.8] are given in table 2.

Table 2: Out of band Spectrum Requirements for ITS G5 systems defined in 2008/671/EC [i.5], ECC/DEC/(08)01 [i.7] and ECC/REC/(08)01 [i.8]

Frequency range	Maximum power, (e.i.r.p.) (dBm)	Reference bandwidth
1 GHz < f < 5,795 GHz	-30	1 MHz
5,795 GHz < f < 5,815 GHz	-65	1 MHz
5,815 GHz < f < 5,850 GHz	-55	1 MHz
5,850 GHz < f < 5,855 GHz	-30	1 MHz
5,925 GHz < f < 5,965 GHz	-65	1 MHz
5,965 GHz < f < 18 GHz	-30	1 MHz

In addition a power control range of 30 dB is required for ITS systems operating in the band 5,855 GHz to 5,925 GHz.

The actual spectrum mask for the ITS allocation in Europe is depicted in figure 1.

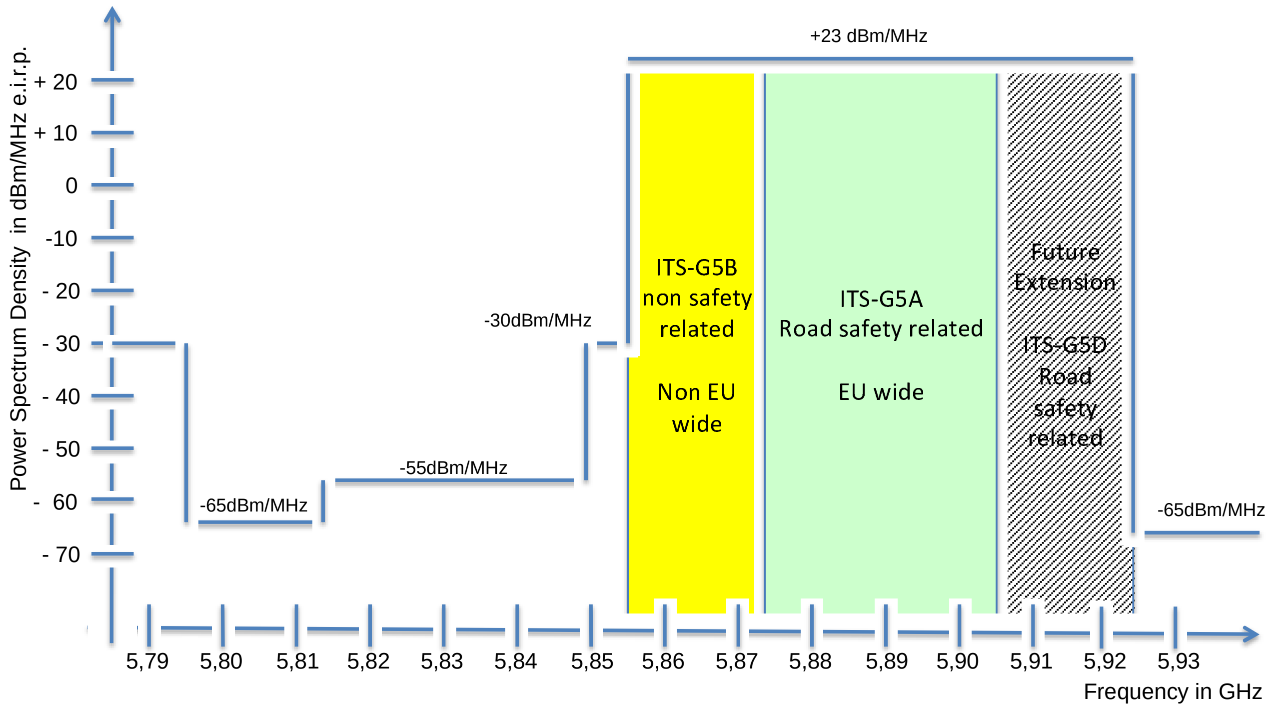

Figure 1: ITS spectrum allocation including out-of-band mask based on 2008/671/EC [i.5], ECC/DEC/(08)01 [i.7] and ECC/REC/(08)01 [i.8]

5.3 Licensing conditions

The spectrum for safety related ITS services should be individual license free.

Important conditions to note are:

- this is a public safety measure to improve road safety and as such politically prioritized;
- the practical problems of licensing in a global car market are immense;
- it is a common experience of the car manufacturers that neither drivers nor car holders are willing to pay for the operation of safety systems, e.g. data transmission fees;
- ITS services are expected to have a very slow take-off if there are costly licensing policies.

5.4 Global usage

Industry is aiming for cost reasons (e.g. usage of components of the shelf to benefit from economy of scale) for frequencies which are globally available, or if that is not possible at least for frequencies which are in the same range as frequency allocations in other regions to allow the usage of the same hardware with different software. This degree of harmonization of frequencies on the global level is necessary since there is a need for these applications throughout the world, and since vehicles are marketed in the global marketplace. Different types of emergency communication system may hinder safety.

Car manufacturers and their suppliers require that the same radio subsystem can be used in all cars. The usage of the same antenna all over the world is an important cost factor for the OEMs because the shape of the car has a large influence on the antenna design.

6 Proposed changes to regulation

6.1 Overview

In Europe the spectrum 5 855 MHz to 5 925 MHz has been identified as spectrum for ITS services split into 5 channel with a bandwidth of 10 MHz each. Three of these channels (5 875 MHz to 5 905 MHz) are allocated for road safety related ITS applications [i.5]. The band 5 855 MHz to 5 875 MHz is reserved for road efficiency and also road safety related applications. The band 5 905 MHz to 5 925 MHz is for future extensions:

- The radiated power levels range from 0 dBm (e.i.r.p.) to 33 dBm (e.i.r.p.) to achieve communication distances of up to 1 000 metres.
- These ITS services need protection which cannot be found in the 5 GHz WLAN frequency bands or in the 5,8 GHz ISM frequency band.
- These bands are harmonized with the US allocation for ITS services in the US [i.2].

The main difference in the allocation is the out-of-band emissions and the spectrum mask in the spurious domain of the ITS systems.

6.2 Spectrum Mask in the out-of band and in the spurious domain

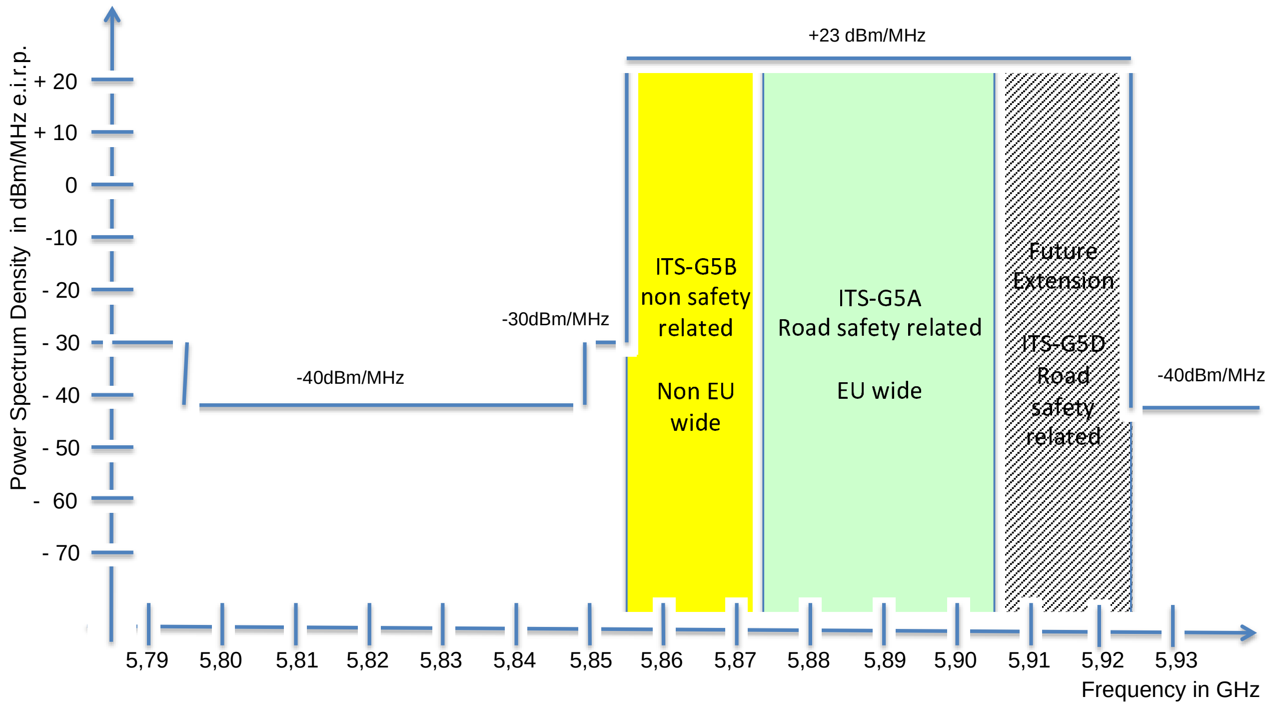

Figure 2: Proposed spectrum regulation with the focus on the out-of-band

The proposed new spectrum has relaxed spectrum restriction in the band 5,795 GHz to 5,850 GHz and above 5,925 GHz.

Additional mitigation mechanisms are required for the frequency range 5,795 GHz < *f* < 5,815 GHz and 5,855 GHz < *f* < 5,925 GHz as described in clause D.3 in order to protect the road tolling.

The proposal in figure 2 is considered to be in line with Recommendation 74-01 which is to be used within a broader context of Recommendations of the ITU-R, dealing with unwanted emissions that are summarized by the ECC/REC/02-05 "Unwanted emissions". In particular, those ITU-R documents contain information and guidance on the applicability and measurement of limits reported in this Recommendation, namely considering:

a) that Recommendation ITU-R SM.329 [i.31] provides options for different categories of limits for unwanted emissions in the spurious domain; moreover it provides some degree of freedom to administrations, for definition of frequency boundaries of spurious domain and the detailed transition of the limits nearby the fundamental emission; in particular it allows, for digital modulations, different definition of spurious emissions frequency boundaries;

b) that Recommendation ITU-R SM.1539 [i.32] and Appendix 3 of the ITU Radio Regulations deal with variation of the boundary between the out-of-band and spurious domains, other than the specific 250 % of the Necessary Bandwidth from the centre frequency of the emission.

No variation or exception from the generic 250 % rule has been set up so far for ITS in the 5 GHz range. Based on an ITS channel bandwidth of 10 MHz, the spurious domain for ITS-G5A (road safety related ITS in 5 875 MHz to 5 905 MHz) begins in the most extreme cases (i.e. for channels with 5,88 GHz or 5,90 GHz centre frequencies) at 5,855 GHz or 5,925 MHz.

According to RR 1.145 Spurious emission: Emission on a frequency or frequencies which are outside the necessary bandwidth and the level of which may be reduced without affecting the corresponding transmission of information. Spurious emissions include harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products but exclude out-of-band emissions. This means for ITS-G5A it should be clarified that the spurious emission limits apply above 5,925 GHz and below the 5,855 MHz frequencies.

6.3 Devices to be included in the regulation

As an addition to the existing regulation including only mobile devices installed in road vehicles for a license exempt regime the updated regulation should cover the following devices under the same regulatory framework:

- infrastructure ITS station for a vehicle-to-roadside and an roadside-to-vehicle communication; and
- portable ITS station included in mobile phone or as standalone devices for inclusion of pedestrians and cyclists into the overall road safety operation.

6.4 Additional possible mitigation factors

Based on the developed set of application for the road safety related deployment some additional mitigation factors have been implemented [i.17] in the overall ITS system concept. These mitigation factors can be taken into account in the evaluation of potential coexistence issues. The message frequency of a CAM message for cooperative awareness applications is being controlled by the speed of the vehicle with a maximum value of 10 Hz. Taking into account the typical message length of 1 ms a duty cycle of 1 % is reached. In addition this message frequency is under control of a Decentralized Congestion Control (DCC) mechanism. This DCC mechanism should prevent the mobile channel from being loaded to more than 75 % in order to guarantee a fair access to the media by all participants in the ITS road safety communication. This mechanism will lead to a reduction in cumulated interference in a give region by reducing the individual duty cycles and/or TX power levels of the devices participating in the communication. All ITS stations will have to follow this control mechanism.

Event based messages might be generated with higher rate in case of an emergency situation. Here the proposed frequency is 20 Hz, leading to a duty cycle of 2 %. These messages are only generated in limited situation like accidents or other safety critical situations (see use case in clause A.1.2.2.3) for a restricted time frame.

Duty cycles of future applications are not yet clear but may be higher than for the already developed applications. One such application is platooning for heavy vehicles. For these applications additional mitigation techniques might be necessary.

For portable ITS stations integrated into smart phones or standalone devices even lower duty cycle can be assumed (see use case in clause A.1.2.2.4). Portable ITS station under portable use cases (not temporarily installed in a vehicle) will send out a CAM only every 500 ms in maximum. The message size will be smaller than in the vehicular case since the amount of data to be transferred is much lower. Taking these considerations into account the maximum duty cycle of ITS stations in portable use cases will be below 0,2 %. Due to implementation issues the maximum TX power of these devices will be below 23 dBm (13 dBm/MHz). Future applications may require higher duty cycles.

In addition, the Harmonized Standard EN 302 571 [i.33] defines a Listen-Before-Talk functionality in the band 5 855 MHz to 5 875 MHz with a detection threshold of -85 dBm e.i.r.p.

7 Main conclusions

7.1 Business importance

The need for ITS data communication and a suitable frequency designation has been recognized for several years and by the allocation of spectrum for the use in road safety related application and road efficiency related application. The national German ITS project SimTD [i.24] has calculated an overall market impact of 200 billion Euros in the time frame from 2015 to 2035 in Germany due to the introduction of cooperative ITS systems. Scaled to the overall inhabitants of Europe this would lead to an overall effect of more than 1 trillion Euros until 2035.

With the WLAN (IEEE 802.11) technology a radio technology is available as a mass product which fulfils technical as well as business requirements. In order to allow for the use of inexpensive standard equipment based on the IEEE 802.11-2012 [i.13] standard an optimization of the spectrum mask in the out-of-band domain and the spurious domain is required.

7.2 Expected timing for ITS to market in Europe

The introduction of ITS systems in Europe is expected to start from 2015 onwards. Due to production planning requirements, it is requested to handle this issue with highest priority.

Annex A: Market information

A.1 Summary of application types

Various projects and groups have investigated a broad set of applications for Vehicle-to-Vehicle and Vehicle-to-Roadside Communications. Some safety related applications are listed in table A.2.

The connectivity required by the applications can be summarized as:

1) Vehicle-Vehicle (this includes multi-hop routing involving several vehicles):
   - Linear (e.g. for convoys of vehicles).
   - Vehicle cluster covering several lanes, co-directional (e.g. for lane management, overtaking assist).
   - Vehicle cluster including opposite direction of travel.
2) Vehicle to roadside (uplink) and roadside to vehicle (downlink):
   - One vehicle to beacon.
   - Beacon to one vehicle.
   - Beacon to many vehicles (broadcast, short range and long range).
   - Beacon to selected vehicles.
3) Cluster of vehicles communications including roadside beacon.
4) Portable ITS stations for pedestrian users participating in road traffic:
   - Awareness applications at pedestrian crossings.
   - Deployment on bicycles and motor cycles.
5) Vehicle-Pedestrian:
   - Periodic safety messages from pedestrians (only the pedestrians close to the road and/or walking along the road).
   - Event-driven messages from pedestrians for lane cross assist.

A.2 Situation outside Europe

A.2.1 North America

ITS technology has a strong position in other regions of the world. North America is the prime example, where Canada and USA have significant developments on these issues. There is a US FCC regulation, published on August 3, 2004 [i.2].

The assigned spectrum for the Dedicated Short Range Communications Service in North America is shown in table A.1. Canada has similar assignments with minor differences.

Table A.1: Assigned spectrum for the Dedicated Short Range Communications (DSRC) service in the US

Channel No.	Frequency range (MHz)	Max. e.i.r.p. (dBm)	Channel use
170	5 850 to 5 855		Reserved
172	5 855 to 5 865	33	Service channel
174	5 865 to 5 875	33	Service channel
175	5 865 to 5 885	23	Service channel
176	5 875 to 5 885	33	Service channel
178	5 885 to 5 895	33/44,8	Control channel
180	5 895 to 5 905	23	Service channel
181	5 895 to 5 915	23	Service channel
182	5 905 to 5 915	23	Service channel
184	5 915 to 5 925	33/40	Service channel

There are two different types of channels:

- Service channels are used to transfer medium to large amounts of data.
- Control channel is used to transmit emergency messages and short broadcast messages, and as a command channel to get IVUs to switch to a service channel when data transfer is needed.

The control channel is exclusively available for safety applications (5,885 GHz to 5,895 GHz, i.e. Ch. 178). Additionally also the channel 5,855 GHz to 5,865 GHz (Ch. 172) is requested to be assigned only for safety applications.

A.2.2 Far East, Australia, South America

China is interested in the CALM M5 and IEEE 802.11-2012 [i.13] work, but there is currently little information on spectrum issues. China has a national standard specifying CEN DSRC on 5,8 GHz for interoperable Electronic Fee Collection systems, and therefore will face a similar interference/coexistence situation as in Europe.

Australia has a national standard specifying CEN DSRC on 5,8 GHz for interoperable Electronic Fee Collection systems, and has large scale national deployments of these. Embargo 48 was issued in April 2008 to protect the 5,9 GHz band (5,850 GHz to 5,925 GHz) from any future assignments, to enable planning for the introduction of ITS into the band.

Major South American countries including Brazil, Chile and Argentina have large scale national deployment of CEN DSRC systems. There is no known spectrum planning on CALM M5/WAVE technology in major South American countries.

A.3 Examples of applications

A.3.1 Overview

The road safety related applications are the driving interest in this technology from both car manufacturers and public authorities.

Road safety is a global concern, and the development in all countries shows that new technology is needed to drive down the number of traffic fatalities. The worldwide research on ITS has invested a lot of work in the analysis of the accident reduction by car-to-car communications.

A.3.2 List of safety related applications

Table A.2 shows an extraction of a list of safety-related ITS applications.

Table A.2: Safety – related applications

Application	Description
Cooperative Collision Warning	Cooperative collision warning collects surrounding vehicle locations and dynamics and warns the driver when a collision is likely.
Work Zone Warning	Work zone safety warning refers to the detection of a vehicle in an active work zone area and the indication of a warning to its driver.
Approaching Emergency Vehicle Warning	This application provides the driver a warning to yield the right of way to an approaching emergency vehicle.
Traffic Signal Violation Warning	Traffic signal violation warning uses infrastructure-to-vehicle communication to warn the driver to stop at the legally prescribed location if the traffic signal indicates a stop and it is predicted that the driver will be in violation.
Pedestrian Activity Alert	This application aids in preventing collisions between pedestrians and vehicles by warning the drivers the presence of potentially dangerous pedestrian situations.
Emergency Vehicle Signal Pre-emption	This application allows an emergency vehicle to request right of way from traffic signals in its direction of travel.
In-Vehicle Signage	The in-vehicle signage application provides the driver with information that is typically conveyed by traffic signs.
Road Condition Warning	Road condition warning is used to provide warning messages to nearby vehicles when the road surface is icy, or when traction is otherwise reduced.
Low Bridge Warning	Low bridge warning is used to provide warning messages especially to commercial vehicles when they are approaching a bridge of low height.
Highway/Rail Collision Warning	Railroad collision avoidance aids in preventing collisions between vehicles and trains on intersecting paths.
Wrong Way Driver Warning	This application warns drivers that a vehicle is driving or about to drive against the flow of traffic.
Emergency Electronic Brake Lights	When a vehicle brakes hard, the Emergency Electronic Brake light application sends a message to other vehicles following behind.
Left Turn Assistant	The Left Turn Assistant application provides information to drivers about oncoming traffic to help them make a left turn at a signalized intersection without a phasing left turn arrow.
Curve Speed Warning	Curve speed warning aids the driver in negotiating curves at appropriate speeds.
Vehicle-Based Road Condition Warning	This in-vehicle application will detect marginal road conditions using on-board systems and sensors (e.g. stability control, ABS), and transmit a road condition warning, if required, to other vehicles via broadcast.
Low Parking Structure Warning	This application provides drivers with information concerning the clearance height of a parking structure.
Lane Change Warning	This application provides a warning to the driver if an intended lane change may cause a crash with a nearby vehicle.
Highway Merge Assistant	This application warns a vehicle on a highway on-ramp if another vehicle is in its merge path (and possibly in its blind spot).
Cooperative Glare Reduction	This application uses C2C-C to allow a vehicle to automatically switch from high-beams to low-beams when trailing another vehicle.
Intelligent Intersection Control	Alerts driver to other vehicles at intersections.
Lane Crossing Assist	Enables pedestrians with special needs to safely cross the road.

A.3.3 Specific applications

A.3.3.1 Workzone warning, figure A.1

- Many accidents occur in work zones.
- Special cones in work zones can be equipped as communicating beacons to warn upcoming traffic about lane closures or speed limits (green cars have ITS).
- Since this is frequently changing information, it cannot be provided by digital maps.

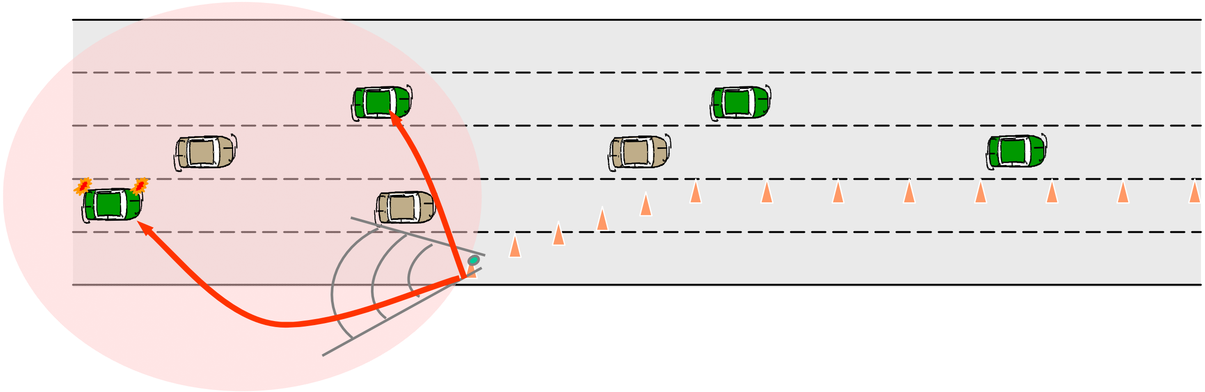

Figure A.1: Workzone warning

A.3.3.2 Emergency vehicle approaching, figure A.2

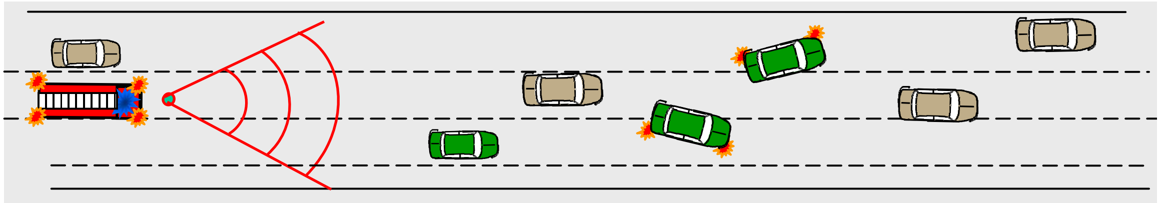

Figure A.2: Emergency vehicle approaching

A.3.3.3 Hazard warning with car-to-car communication, figure A.3

- Vehicles switching on their warning lights send out a warning message to the following traffic to avoid rear-end collisions.
- The communication might be initiated by an airbag-sensor, switching on warning lights, etc.

- This information reaches upcoming traffic much faster than conventional methods.

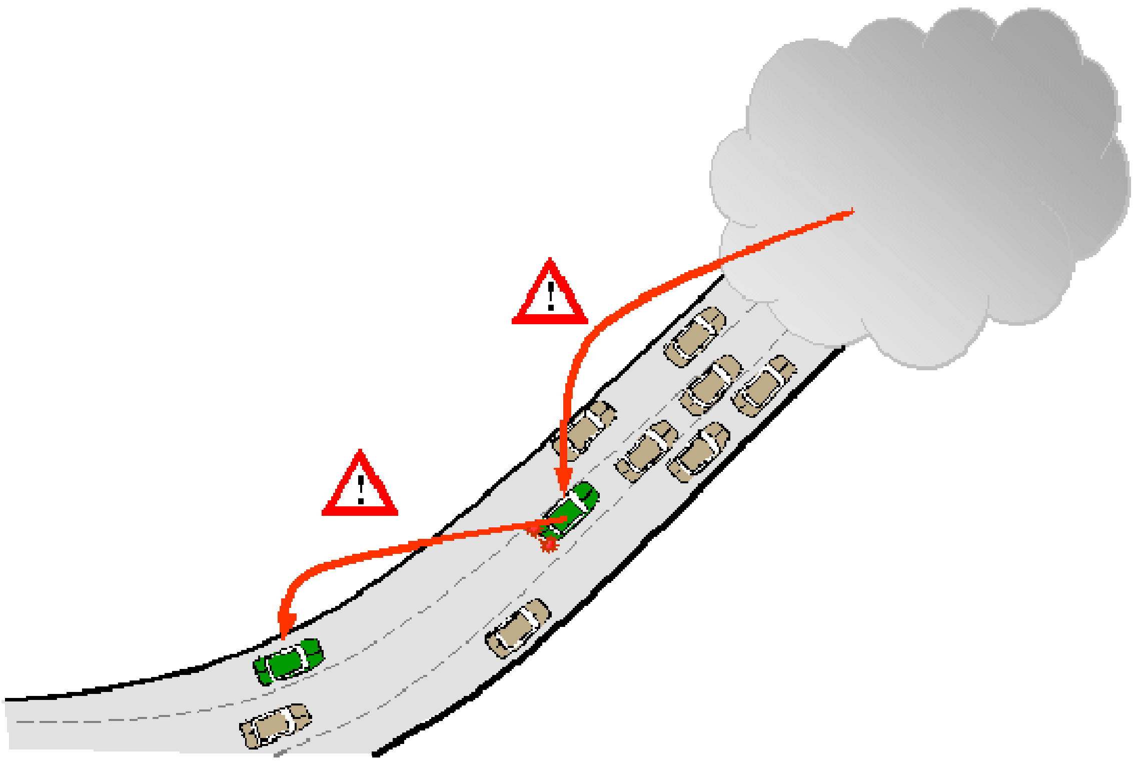

Figure A.3: Hazard warning

A.3.3.4 Pedestrian Activity Alert, figure A.4

- Pedestrians equipped with mobile ITS devices transmit periodic status messages when they are deemed to be participating in the roadways.
- When vehicles approach pedestrians, (e.g. pedestrian walking along a highway, pedestrian crossing lanes in places not defined for crossing, people with disabilities, etc.) the messages are used to identify the approach is potentially dangerous by inspecting the received messages.
- The warnings are communicated to the driver and/or used to enable driver assist systems.

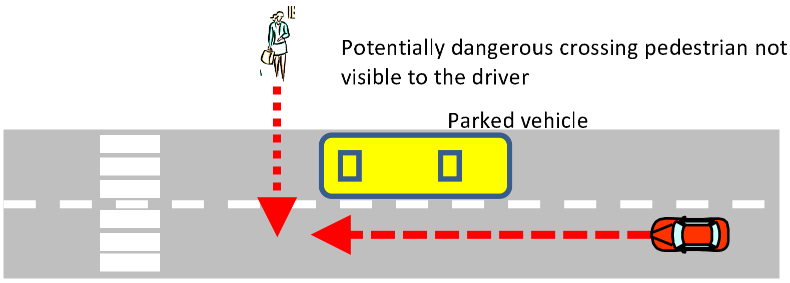

Figure A.4: Pedestrian warning

A.4 Market size and value

The European market for RTTT services is growing. At present, the number of applications implemented is small compared with the number considered to be valuable by analysts drawn from the automotive industry, road operators, road users, governmental and environmental bodies. Key requirements for growth are effective, multi-application communication systems and a set of service providers responsive to the users' needs and to the economic/commercial opportunities.

One common characteristic of all safety-related C2C-communication applications is the lack of communication partners during the system introduction phase. A certain penetration of equipped cars is required to realize the advantage of the system for traffic safety. Drivers will not accept the system if there is no benefit right from the beginning of operation. For example, if a driver ran into a traffic jam without having received a warning message, he would be irritated, which would result in a strong negative impact on how the whole system is considered. If the penetration rate is too low, there will be a significant probability that no equipped vehicle is located in a traffic jam and thus this situation will occur.

For this reason non-safety applications which offer immediate benefit to car holders and drivers have to be implemented to overcome the introduction phase characterized by low penetration rates. These 'deployment applications' typically rely on data exchange between vehicles and fixed stations. Hotspot access at gas stations gives the possibility to get information about restaurants, sightseeing points, or traffic data along the anticipated route. Other examples are wireless media file exchange at home and wireless diagnosis at workshops.

For the deployment applications, the V2V-communication system will use the WLAN frequencies in the 5 GHz band obeying the existing regulations. For these applications sufficient bandwidth is already allocated in that frequency range. The development, implementation, and maybe operation of information applications will offer new market opportunities for European industrial organizations.

The vicinity to the 5 GHz WLAN spectrum is the premise for a cost-efficient multi-application communication systems providing the capability for traffic safety.

The microwave communication system outlined in the present document has the capability of meeting a wide range of the data link requirements, through its scope for a high data rate, time-division and/or channelized architecture. It is capable of interfacing with existing or developing MAC protocols devised for mobile and dynamic networks.

It is expected that roadside units will eventually be present at regular intervals along all inter-urban trunk routes, at strategic locations (e.g. filling stations, car parks) for high capacity services, and at locations of opportunity (e.g. sides of buildings, lamp posts, traffic signs) in urban areas.

In-vehicle units will eventually be fitted to all new vehicles (domestic and commercial), and retro-fitted on an operator/owner-demand basis to a proportion of existing vehicles.

It is likely that a full take-up will require at least fifteen years, but together with data hotspots and roadside units associated in-vehicle units can be implemented much more quickly.

For market rollout, it is important that the use of the communication system is available both for official (i.e. safety, public information and road management) and for commercial purposes, so that viable business cases can be established.

The standards for operation should be such that an evolutionary roll-out is possible, with backward-compatibility so as not adversely to affect early enterers.

The need for ITS data communication and a suitable frequency designation has been recognized for several years and by the allocation of spectrum for the use in road safety related application and road efficiency related application. The national German ITS project SimTD [i.24] has calculated an overall market impact of 200 billion Euros in the time frame from 2015 to 2035 in Germany due to the introduction of cooperative ITS systems. Scaled to the overall population of Europe this would lead to an overall effect of more than 1 trillion Euros until 2035.

A.5 Traffic evaluation

The functionality required of a high data rate and low latency communication system for next-generation transport telematics is that it should support V2V-and V2R-communication in a dynamic traffic environment, in a range of weather conditions, and with communication ranges extending to several hundred metres. It should be capable of providing broadcast, point-to-point and vehicle cluster connectivity.

The communications traffic will be distributed over a wide area of a country, with a user density heavily dependent on the traffic scenarios.

However, it is to note that:

a) Only one ITS transmitting device uses a frequency channel at the same time using listen-before-talk and transmitter power reduction and duty cycle restriction in congestion situations.

b) The maximum duty cycle of a single ITS station in the band 5,855 GHz to 5,925 GHz will be below 2,5 % with an average value well below 1 % measured over one second.

c) Portable ITS station in portable use cases will have a duty cycle below 0,2 % and maximum TX power levels of 23 dBm.

d) The frequency re-use distance depends on the ITS transmitter power and varies between 15 metres to 1 000 metres.

The average conveyed ITS message duration can be assumed to be below one millisecond.

Annex B: Technical information

B.1 Technical description

B.1.1 IEEE 802.11-2012

Technology for microwave communications in Wireless LANs has been available for several years, but until recently it has not been deployed in mobile scenarios. The recent increase in maturity of WLAN technology and availability of high-performance, low-cost products has meant that commercial interest in practical systems for transport telematics applications is rising, and experimental prototype systems are being developed, including the design of chipsets for use in the 5 GHz band.

The basis for this technology is a variant of the IEEE 802.11a [i.12] and IEEE 802.11j [i.11] standards included in the IEEE 802.11-2012 [i.13].

Directional data links and broadcast communications can be established depending on the applications.

The spectrum usage is such that large amounts of bandwidth can be available to support high data rate applications and/or multiple applications simultaneously.

There are currently several options being investigated in how the frequency range can be used. Some applications require a very high data rate (e.g. a short range information hotspot), some are longer range with a medium data rate, and some have a low data requirement, but need to coexist with others.

The MAC protocol needs to be chosen with care. There are advantages in 802.11a [i.12], as it is linked to the modulation and data structure scheme in a way that allows the basic connectivity to be realized, which provides automatic data rate and modulation scheme selection in cases of low received signal strength, and which has an inbuilt frequency offset compensation mechanism that will enable Doppler compensation to be provided.
IEEE 802.11-2012 [i.13] defines a WLAN standard (known as WAVE – Wireless Access in the Vehicular Environment) with V2V and V2R connectivity for 5,9 GHz systems in view. This is a variant of 802.11a [i.12] which has an architecture specified to allow faster real-time operation in a dynamic environment.

It is relevant that ISO TC204 WG16 is working towards an architecture (referred to as CALM) that allows a range of applications to be matched to a set of communication bearers, with a management layer determining the linkage according to the requirements of the applications and the functionality of the bearer. A microwave communication system is envisaged as being one of these bearers, and so an appropriate interface should be provided to allow interoperability with the CALM architecture.

International compatibility is important. ETSI and ISO have a close co-operation to handle this requirement.

The WAVE standard has been published by IEEE as part of the WLAN standard IEEE 802.11-2012 in 2012.

B.1.2 System parameters

Table B.1: System parameters (not exhaustive)

Parameter	Value	Comments
Frequency stability	1 ppm	This figure takes account of the frequency tolerance allowed by IEEE 802.11a [i.12] together with the expected Doppler variation from a vehicle closing speed of 400 km/h.
Maximum radiated power	33 dBm e.i.r.p.	Transmitter power control (TPC) with a 30 dB range. Equipment classes: A 10 dBm B 20 dBm C 33 dBm
Antenna beam shape/gain	N/A	No beam shape is specified (in line with current decision of ISO TC204 WG16.1). The user will specify a beam shape in accordance with the coverage required by the set of applications to be supported, or the manufacturer will offer a number of antenna options.
Polarization	TBD	Circular and linear each have benefits. Some degree of rejection of emissions from oppositely travelling vehicles may be required.
Modulation scheme	BPSK QPSK 16QAM 64QAM	This is the standard set within IEEE 802.11-2012 [i.13].
Data rates	3/4,5/6/9/12/18/ 24/27 Mbit/s	This is the standard set within IEEE 802.11-2012 [i.13]. As an option two channels may be combined to produce double data rates (up to 54 Mbit/s). Default data rate is 6 Mbit/s.
Channel Bandwidth	10 MHz, option 20 MHz	This is the standard set within IEEE 802.11-2012 [i.13].
Communication mode	Half-duplex, broadcast	Half-duplex and broadcast are believed to be adequate for the applications considered to date.

ITS spectrum mask:

Table B.2: Spectrum mask per equipment Class

(in dBc)	±4,5 MHz Offset	±5,0 MHz Offset	±5,5 MHz Offset	±10 MHz Offset	±15 MHz Offset
Class A	0	-10	-20	-28	-40
Class B	0	-16	-20	-28	-40
Class C	0	-26	-32	-40	-50
NOTE: The definition of equipment Classes is given in the row for 'Maximum radiated power' in table B.1.					

B.2 Technical justification for spectrum

B.2.1 Introduction

The public 5 GHz channels for WLAN IEEE 802.11a [i.12] and IEEE 802.11h [i.14] (5 150 MHz to 5 350 MHz and 5 470 MHz to 5 725 MHz), as identified in ECC/DEC/(04)08 [i.1], cannot be used for high priority safety related ITS applications. A dedicated spectrum is necessary for safety critical ITS applications. Furthermore, the WLAN system IEEE 802.11a [i.12] and IEEE 802.11h [i.14] is not applicable for vehicular-to-vehicular communications for the following reasons:

- Sharing the spectrum with users of public WLAN channels causes unacceptable levels of interference to safety critical applications.
- IEEE 802.11h [i.14] implements a DFS mechanism to avoid co-channel operation with radar systems. DFS requires to mute all transmissions on a channel to test for the presence of a radar. For time critical safety applications this mechanism is impractical.

- Safety critical applications require protection and prioritization over public WLAN applications that can allocate channels for several seconds.
- The WLAN system uses channels with 20 MHz bandwidth. For vehicular-to-vehicular communications a 10 MHz channel bandwidth is used to obtain larger communication ranges and to reduce the symbol interference. The bisection of the bandwidth increases the Guard Interval (GI) to 1,6 µs which is necessary to cope with the severe multi-path environments expected in highly reflective vehicular environments.

An analysis of vehicular-to-vehicular communication applications results in the requirement to support about 3 Mbit/s over communication ranges of up to 1 000 metres. Certain applications require larger data rates, e.g. communication with hot-spots. However, for these applications the communication range is in the order of tens of metres.

For the e.i.r.p. proposed in clause B.1.2 communication ranges up to 1 000 metres can be supported. The actual communication range depends on the data rate and the environmental conditions. Severe impacts are expected from the physical properties of the communication channel, e.g. line-of-sight or non-line-of-sight conditions. However, at the proposed carrier frequency (5,9 GHz) the path loss is hardly influenced by weather conditions such as rain, snow, and dust.

To justify the requested e.i.r.p. a detailed link budget has been evaluated which is presented in the following summary. From this analysis it follows that an e.i.r.p. of 33 dBm is required to achieve a transmission range of about 1 000 metres for typical environments with sufficient link quality.

For the link budget calculation it is assumed to use omni-directional roof antennas with an antenna gain of 3 dBi. This assumption is proper for all kind of situations, such as typical communication in the direction of travel, all around communication in case of undefined orientation after an accident, or at intersections in the direction of all lanes.

For the calculations a carrier frequency of 5,9 GHz or, equally, a wavelength of 5,08 cm is assumed.

Table B.3: Minimum receiver sensitivity for a BW of 10 MHz

Data Rate (Mbits/s)	Minimum Sensitivity (dBm)
3	–85
4,5	–84
6	–72
9	–80
12	–77
18	–70
24	–69
27	–67

The proposed PHY and MAC is akin to IEEE 802.11a [i.12] using a BW of 10 MHz. The link budget calculated here assumes data rates and minimum receiver sensitivities shown in table B.3. The data rates are gross values for all possible combinations of symbol alphabets (i.e. BPSK, QPSK, 16QAM, and 64QAM symbol constellation) and code rates (i.e. ½-rate and ¾-rate code). The minimum receive sensitivity specifies the required receive input power (i.e. at the antenna connection) including an implementation margin of 5 dB for a receiver noise figure of 10 dB and a BER of 10^{-5}.

B.2.2 Link budget

The link budget is calculated in dBm as:

$$P_e = P_s + G_s + G_e + L$$

where P_e is the received power in dBm, P_s is the transmit power in dBm, G_s is the transmit antenna gain in dBi, G_e is the receive antenna gain in dBi, and L is the path loss in dB. Note that e.i.r.p. = $P_s + G_s$. To account for the increased path loss coefficient, the total path loss is split up into two contributions:

$$L = L_0 + L_1$$

where:

$$L_0 = 20 \log\left(\frac{\lambda}{4\pi d_0}\right)$$

- is the path loss in dB up to the breakpoint d_0 = 15 m where free space transmission is given; and

$$L_1 = 10 \log\left(\frac{d}{d_0}\right)^n$$

- is the path loss in dB from distance d_0 to d assuming a path loss coefficient n = 2,7.

For an e.i.r.p. = 33 dBm, $G_s = G_e$ = 3 dBi, and d = 1 000 m we obtain a received power of P_e = -84 dBm. The link budget calculation is illustrated in figure B.1. Comparing P_e with the minimum receive sensitivities in table B.3, we obtain that for the requested e.i.r.p. data rates of 3 Mbit/s and possibly 4,5 Mbit/s can be supported over a range of about 1 000 metres. Note that for an e.i.r.p. = 30 dBm as specified for IEEE 802.11a [i.12] this communication range cannot be achieved.

Finally, note that for non-line-of-sight conditions it is well documented for mobile communications that the path loss coefficient is in the range $n \approx 3 \ldots 5$. E.g. assuming n = 4, e.i.r.p. = 33 dBm, and a data rate of 3 Mbit/s a maximum communication range of 240 metres is obtained.

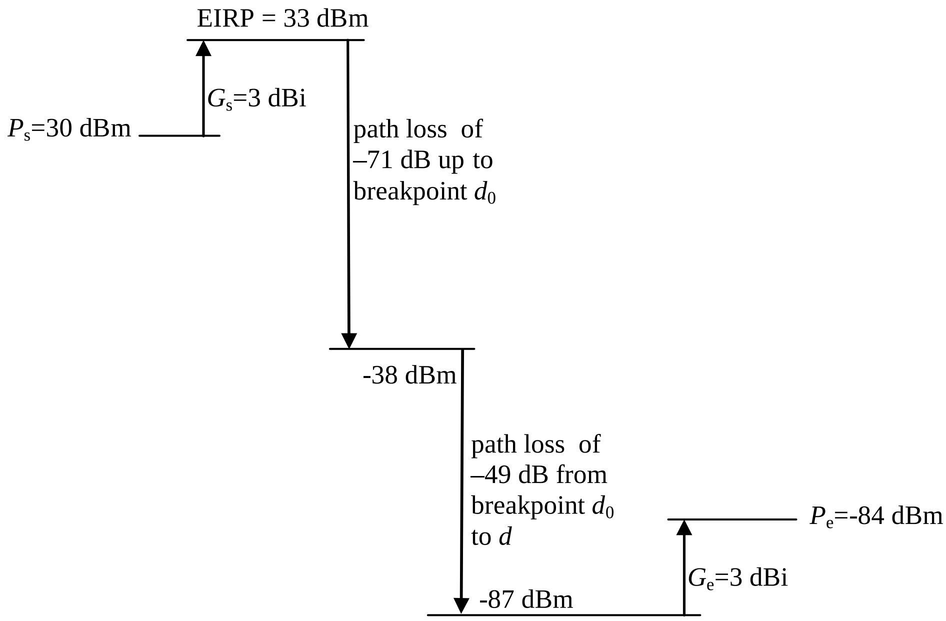

Figure B.1: Illustration of the link budget calculation

B.3 Information on current version of relevant standards

TR 101 607 [i.16] includes the standards developed under the mandate 453 [i.20] and was agreed in early 2013 as the Release 1 for ITS in the spectrum 5 855 MHz to 5 925 MHz.

Annex C: Expected compatibility issues

C.1 General Coexistence studies

Coexistence studies with existing radio services in the 5 GHz range have been performed in the scope of the initial allocation of the ITS spectrum in Europe [i.9], [i.10]. The following table gives the European allocations in the 5 GHz range. Frequency ranges with current allocations for license-exempt applications (e.g. WLAN, ISM) or applications like the microwave landing system are not desired for these applications. Only a limited set of services mentioned in the table below are relevant for further coexistence studies and investigation for the new regulatory framework for the ITS services in Europe.

Table C.1

Frequency band (MHz)	ITU Radio Regulations Region 1 allocation to services	European Common Allocation [i.21]	Utilization in ECA Table [i.21]
5 000 to 5 010	AERONAUTICAL RADIONAVIGATION RADIONAVIGATION-SATELLITE (Earth-to-space) 5.367	AERONAUTICAL RADIONAVIGATION RADIONAVIGATION-SATELLITE (E/S) Radio Astronomy Space Research (passive) 5.367 5.443B	Radio astronomy applications Satellite Navigation
5 150 to 5 250	AERONAUTICAL RADIONAVIGATION FIXED-SATELLITE (Earth-to-space) 5.447A MOBILE except aeronautical mobile 5.446A 5.446B 5.446 5.447 5.447B 5.447C	FIXED-SATELLITE (E/S) 5.447A MOBILE except Aeronautical Mobile 5.446A 5.446B 5.446 5.447 5.447B 5.447C	Feederlinks for MSS Wireless Access Systems incl Radio Local Area Networks
5 250 to 5 255	EARTH EXPLORATION-SATELLITE (active) RADIOLOCATION SPACE RESEARCH 5.447D MOBILE except aeronautical mobile 5.446A 5.447F 5.447E 5.448 5.448A	EARTH EXPLORATION-SATELLITE (active) MOBILE except Aeronautical Mobile 5.446A 5.447F RADIOLOCATION SPACE RESEARCH 5.447D 5.448A EU2 EU22	Active Sensors Position fixing Shipborne and VTS radar Tactical radars Weapon system radars Weather radars Wireless Access Systems incl Radio Local Area Networks
5 255 to 5 350	EARTH EXPLORATION-SATELLITE (active) RADIOLOCATION SPACE RESEARCH (active) MOBILE except aeronautical mobile 5.446A 5.447F 5.447E 5.448 5.448A	EARTH EXPLORATION-SATELLITE (active) MOBILE except Aeronautical Mobile 5.446A 5.447F RADIOLOCATION SPACE RESEARCH (active) 5.448A EU2 EU22	Active Sensors Position fixing Shipborne and VTS radar Tactical radars Weapon system radars Weather radars Wireless Access Systems incl Radio Local Area Networks
5 350 to 5 450	EARTH EXPLORATION-SATELLITE (active) 5.448B SPACE RESEARCH (active) 5.448C AERONAUTICAL RADIONAVIGATION 5.449 RADIOLOCATION 5.448D	AERONAUTICAL RADIONAVIGATION 5.449 EARTH EXPLORATION-SATELLITE (active) 5.448B RADIOLOCATION 5.448D SPACE RESEARCH (active) 5.448C Fixed EU2 EU22	Active Sensors Position fixing Shipborne and VTS radar Tactical radars Weapon system radars Weather radars

Frequency band (MHz)	ITU Radio Regulations Region 1 allocation to services	European Common Allocation [i.21]	Utilization in ECA Table [i.21]
5 450 to 5 460	EARTH EXPLORATION-SATELLITE (active) 5.448B SPACE RESEARCH (active) 5.448C AERONAUTICAL RADIONAVIGATION 5.449 RADIOLOCATION 5.448D	AERONAUTICAL RADIONAVIGATION 5.449 EARTH EXPLORATION-SATELLITE (active) 5.448B RADIOLOCATION 5.448D SPACE RESEARCH (active) 5.448C EU2 EU22	Active Sensors Position fixing Shipborne and VTS radar Tactical radars Weapon system radars Weather radars
5 460 to 5 470	RADIONAVIGATION 5.449 EARTH EXPLORATION-SATELLITE (active) SPACE RESEARCH (active) RADIOLOCATION 5.448D 5.448B	EARTH EXPLORATION-SATELLITE (active) RADIOLOCATION 5.448D RADIONAVIGATION 5. 449 SPACE RESEARCH (active) 5.448B EU2 EU22	Active Sensors Position fixing Shipborne and VTS radar Tactical radars Weapon system radars Weather radars
5 470 to 5 570	MARITIME RADIONAVIGATION MOBILE except aeronautical mobile 5.446A 5.450A EARTH EXPLORATION-SATELLITE (active) SPACE RESEARCH (active) RADIOLOCATION 5.450B 5.448B 5.450 5.451	EARTH EXPLORATION-SATELLITE (active) MARITIME RADIONAVIGATION MOBILE except Aeronautical Mobile 5.446A 5.450A RADIOLOCATION 5.450B SPACE RESEARCH (active) 5.448B EU2 5.452 EU22	Active Sensors Position fixing Shipborne and VTS radar Tactical radars Weapon system radars Weather radars Wireless Access Systems incl Radio Local Area Networks
5 570 to 5 650	MARITIME RADIONAVIGATION MOBILE except aeronautical mobile 5.446A 5.450A RADIOLOCATION 5.450B 5.450 5.451 5.452	MARITIME RADIONAVIGATION MOBILE except Aeronautical Mobile 5.446A 5.450A RADIOLOCATION 5.450B 5.452	Position fixing Shipborne and VTS radar Tactical radars Weapon system radars Wireless Access Systems incl Radio Local Area Networks
5 650 to 5 725	RADIOLOCATION MOBILE except aeronautical mobile 5.446A 5.450A Amateur Space research (deep space) 5.282 5.451 5.453 5.454 5.455	MOBILE except Aeronautical Mobile 5.446A 5.450A RADIOLOCATION Amateur 5.282 EU2 EU17 EU22	Amateur applications (Within 5 660 MHz to 5 670 MHz); Amateur Satellite applications (E/S) (Within 5 660 MHz to 5 670 MHz) ; Position fixing Shipborne and VTS radar Tactical radars Weapon system radars Weather radars Wireless Access Systems incl Radio Local Area Networks
5 725 to 5 830	FIXED-SATELLITE (Earth-to-space) RADIOLOCATION Amateur 5.150 5.451 5.453 5.455 5.456	FIXED-SATELLITE (E/S) RADIOLOCATION Amateur Mobile 5.150 EU2 EU22	Amateur applications; ISM (Within the band 5 725 MHz to 5 875 MHz); Non civil radiolocation ; Non specific SRD (Within the band 5 725 MHz to 5 875 MHz); Road Transport and Traffic Telematic Systems (RTTT) (Within the band 5 795 MHz to 5 805 MHz; RTTT in the band 5 805 MHz to 5 815 MHz on a national basis); Weather radars

Frequency band (MHz)	ITU Radio Regulations Region 1 allocation to services	European Common Allocation [i.21]	Utilization in ECA Table [i.21]
5 830 to 5 850	FIXED-SATELLITE (Earth-to-space) RADIOLOCATION Amateur Amateur-satellite (space-to-Earth) 5.150 5.451 5.453 5.455 5.456	FIXED-SATELLITE (E/S) RADIOLOCATION Amateur Amateur-Satellite (S/E) Mobile 5.150 EU2 EU22	Amateur Satellite applications (S/E) (Within the band 5 830 MHz to 5 850 MHz); ISM (Within the band 5 725 MHz to 5 875 MHz); Non civil radiolocation ; Non specific SRD (Within the band 5 725 MHz to 5 875 MHz); Weather radars
5 850 to 5 925	FIXED FIXED-SATELLITE (Earth-to-space) MOBILE 5.150	FIXED FIXED-SATELLITE (E/S) MOBILE 5.150	Coordinated earth stations in FSS; ISM (Within the band 5 725 MHz to 5 875 MHz); Non specific SRD (Within the band 5 725 MHz to 5 875 MHz)
5 925 to 6 425	FIXED FIXED-SATELLITE (Earth-to-space) 5.457A 5.457B MOBILE 5.440	FIXED FIXED-SATELLITE (E/S) 5.457A	Coordinated earth stations in FSS Medium/high capacity fixed links
5.150	The following bands: 13 553 kHz to 13 567 kHz (centre frequency 13 560 kHz); 26 957 kHz to 27 283 kHz (centre frequency 27 120 kHz); 40,66 MHz to 40,70 MHz (centre frequency 40,68 MHz); 902 MHz to 928 MHz in Region 2 (centre frequency 915 MHz); 2 400 MHz to 2 500 MHz (centre frequency 2 450 MHz); 5 725 MHz to 5 875 MHz (centre frequency 5 800 MHz); and 24 GHz to 24,25 GHz (centre frequency 24,125 GHz); are also designated for industrial, scientific and medical (ISM) applications. Radiocommunication 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**.		
5.282	In the bands 435 MHz to 438 MHz, 1 260 MHz to 1 270 MHz, 2 400 MHz to 2 450 MHz, 3 400 MHz to 3 410 MHz (in Regions 2 and 3 only) and 5 650 MHz to 5 670 MHz, the amateur-satellite service may operate subject to not causing harmful interference to other services operating in accordance with the table (see No. 5.43). Administrations authorizing such use shall ensure that any harmful interference caused by emissions from a station in the amateur-satellite service is immediately eliminated in accordance with the provisions of No. 25.11. The use of the bands 1 260 MHz to 1 270 MHz and 5 650 MHz to 5 670 MHz by the amateur-satellite service is limited to the Earth-to-space direction.		
5.328B	The use of the bands 1 164 MHz to 1 300 MHz, 1 559 MHz to 1 610 MHz and 5 010 MHz to 5 030 MHz by systems and networks in the radionavigation-satellite service for which complete coordination or notification information, as appropriate, is received by the Radiocommunication Bureau after 1 January 2005 is subject to the application of the provisions of Nos. 9.12, 9.12A and 9.13. Resolution 610 (WRC-03) shall also apply. (WRC-03)		
5.367	Additional allocation: the bands 1 610 MHz to 1 626,5 MHz and 5 000 MHz to 5 150 MHz are also allocated to the aeronautical mobile-satellite I service on a primary basis, subject to agreement obtained under No. 9.21.		
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**.		
5.443B	In order not to cause harmful interference to the microwave landing system operating above 5 030 MHz, the aggregate power flux-density produced at the Earth's surface in the band 5 030 MHz to 5 150 MHz by all the space stations within any radionavigation-satellite service system (space-to-Earth) operating in the band 5 010 MHz to 5 030 MHz shall not exceed –124,5 dB(W/m^2) in a 150 kHz band. In order not to cause harmful interference to the radio astronomy service in the band 4 990 MHz to 5 000 MHz, radionavigation-satellite service systems operating in the band 5 010 MHz to 5 030 MHz shall comply with the limits in the band 4 990 MHz to 5 000 MHz defined in Resolution **741 (WRC-03)**. (WRC-03)		
5.444	The band 5 030 MHz to 5 150 MHz is to be used for the operation of the international standard system (microwave landing system) for precision approach and landing. The requirements of this system shall take precedence over other uses of this band. For the use of this band, No. **5.444A** and Resolution **114 (Rev.WRC-03)** apply. (WRC-03)		

Frequency band (MHz)	ITU Radio Regulations Region 1 allocation to services	European Common Allocation [i.21]	Utilization in ECA Table [i.21]
5.444A	*Additional allocation:* the band 5 091 MHz to 5 150 MHz is also allocated to the fixed-satellite service (Earth-to-space) on a primary basis. This allocation is limited to feeder links of non-geostationary mobile-satellite systems in the mobile-satellite service and is subject to coordination under No. **9.11A**. In the band 5 091 MHz to 5 150 MHz, the following conditions also apply: - prior to 1 January 2018, the use of the band 5 091 MHz to 5 150 MHz by feeder links of non-geostationary-satellite systems in the mobile-satellite service shall be made in accordance with Resolution **114 (Rev.WRC-03)**; - prior to 1 January 2018, the requirements of existing and planned international standard systems for the aeronautical radionavigation service which cannot be met in the 5 000 MHz to 5 091 MHz band, shall take precedence over other uses of this band; - after 1 January 2012, no new assignments shall be made to earth stations providing feeder links of non-geostationary mobile-satellite systems; - after 1 January 2018, the fixed-satellite service will become secondary to the aeronautical radionavigation service. (WRC-03)		
5.446	*Additional allocation:* in the countries listed in Nos. **5.369** and **5.400**, the band 5 150 MHz to 5 216 MHz is also allocated to the radiodetermination-satellite service (space-to-Earth) on a primary basis, subject to agreement obtained under No. **9.21**. In Region 2, the band is also allocated to the radiodetermination-satellite service (space-to-Earth) on a primary basis. In Regions 1 and 3, except those countries listed in Nos. **5.369** and **5.400**, the band is also allocated to the radiodetermination-satellite service (space-to-Earth) on a secondary basis. The use by the radiodetermination-satellite service is limited to feeder links in conjunction with the radiodetermination-satellite service operating in the bands 1 610 MHz to 1 626,5 MHz and/or 2 483,5 MHz to 2 500 MHz. The total power flux-density at the Earth's surface shall in no case exceed –159 dB(W/m2) in any 4 kHz band for all angles of arrival.		
5.446A	The use of the bands 5 150 MHz to 5 350 MHz and 5 470 MHz to 5 725 MHz by the stations in the mobile service shall be in accordance with Resolution **229 (WRC-03)**. (WRC-03)		
5.446B	In the band 5 150 MHz to 5 250 MHz, stations in the mobile service shall not claim protection from earth stations in the fixed-satellite service. No. **5.43A** does not apply to the mobile service with respect to fixed-satellite service earth stations. (WRC-03)		
5.447	*Additional allocation:* in Israel, Lebanon, Pakistan, the Syrian Arab Republic and Tunisia, the band 5 150 MHz to 5 250 MHz is also allocated to the mobile service, on a primary basis, subject to agreement obtained under No. **9.21**. In this case, the provisions of Resolution **229 (WRC-03)** do not apply. (WRC-03)		
5.447A	The allocation to the fixed-satellite service (Earth-to-space) is limited to feeder links of non-geostationary-satellite systems in the mobile-satellite service and is subject to coordination under No. **9.11A**.		
5.447B	*Additional allocation*: the band 5 150 MHz to 5 216 MHz is also allocated to the fixed-satellite service (space-to-Earth) on a primary basis. This allocation is limited to feeder links of non-geostationary-satellite systems in the mobile-satellite service and is subject to provisions of No. **9.11A**. The power flux-density at the Earth's surface produced by space stations of the fixed-satellite service operating in the space-to-Earth direction in the band 5 150 MHz to 5 216 MHz shall in no case exceed –164 dB(W/m^2) in any 4 kHz band for all angles of arrival.		
5.447C	Administrations responsible for fixed-satellite service networks in the band 5 150 MHz to 5 250 MHz operated under Nos. **5.447A** and **5.447B** shall coordinate on an equal basis in accordance with No. **9.11A** with administrations responsible for non-geostationary-satellite networks operated under No. **5.446** and brought into use prior to 17 November 1995. Satellite networks operated under No. **5.446** brought into use after 17 November 1995 shall not claim protection from, and shall not cause harmful interference to, stations of the fixed-satellite service operated under Nos. **5.447A** and **5.447B**.		
5.447D	The allocation of the band 5 250 MHz to 5 255 MHz to the space research service on a primary basis is limited to active spaceborne sensors. Other uses of the band by the space research service are on a secondary basis. (WRC-97)		
5.447E	*Additional allocation:* the band 5 250 MHz to 5 350 MHz is also allocated to the fixed service on a primary basis in the following countries in Region 3: Australia, Korea (Rep. of), India, Indonesia, Iran (Islamic Republic of), Japan, Malaysia, Papua New Guinea, the Philippines, Sri Lanka, Thailand and Viet Nam. The use of this band by the fixed service is intended for the implementation of fixed wireless access systems and shall comply with Recommendation ITU-R F.1613 [i.22]. In addition, the fixed service shall not claim protection from the radiodetermination, Earth exploration-satellite (active) and space research (active) services, but the provisions of No. **5.43A** do not apply to the fixed service with respect to the Earth exploration-satellite (active) and space research (active) services. After implementation of fixed wireless access systems in the fixed service with protection for the existing radiodetermination systems, no more stringent constraints should be imposed on the fixed wireless access systems by future radiodetermination implementations. (WRC-03)		
5.447F	In the band 5 250 MHz to 5 350 MHz, stations in the mobile service shall not claim protection from the radiolocation service, the Earth exploration-satellite service (active) and the space research service (active). These services shall not impose on the mobile service more stringent protection criteria, based on system characteristics and interference criteria, than those stated in Recommendations Recommendation ITU-R M.1638 [i.23] and Recommendation ITU-R SA.1632 [i.24]. (WRC-03)		

Frequency band (MHz)	ITU Radio Regulations Region 1 allocation to services	European Common Allocation [i.21]	Utilization in ECA Table [i.21]
5.448	*Additional allocation:* in Azerbaijan, Libyan Arab Jamahiriya, Mongolia, Kyrgyzstan, Slovakia, Romania and Turkmenistan, the band 5 250 MHz to 5 350 MHz is also allocated to the radionavigation service on a primary basis. (WRC-03)		
5.448A	The Earth exploration-satellite (active) and space research (active) services in the frequency band 5 250 MHz to 5 350 MHz shall not claim protection from the radiolocation service. No. **5.43A** does not apply. (WRC-03)		
5.448B	The Earth exploration-satellite service (active) operating in the band 5 350 MHz to 5 570 MHz and space research service (active) operating in the band 5 460 MHz to 5 570 MHz shall not cause harmful interference to the aeronautical radionavigation service in the band 5 350 MHz to 5 460 MHz, the radionavigation service in the band 5 460 MHz to 5 470 MHz and the maritime radionavigation service in the band 5 470 MHz to 5 570 MHz. (WRC-03)		
5.448C	The space research service (active) operating in the band 5 350 MHz to 5 460 MHz shall not cause harmful interference to nor claim protection from other services to which this band is allocated. (WRC-03)		
5.448D	In the frequency band 5 350 MHz to 5 470 MHz, stations in the radiolocation service shall not cause harmful interference to, nor claim protection from, radar systems in the aeronautical radionavigation service operating in accordance with No. **5.449** (WRC-03)		
5.449	The use of the band 5 350 MHz to 5 470 MHz by the aeronautical radionavigation service is limited to airborne radars and associated airborne beacons.		
5.450	*Additional allocation:* in Austria, Azerbaijan, Iran (Islamic Republic of), Mongolia, Kyrgyzstan, Romania, Turkmenistan and Ukraine, the band 5 470 MHz to 5 650 MHz is also allocated to the aeronautical radionavigation service on a primary basis. (WRC-03)		
5.450A	In the band 5 470 MHz to 5 725 MHz, stations in the mobile service shall not claim protection from radio-determination services. Radiodetermination services shall not impose on the mobile service more stringent protection criteria, based on system characteristics and interference criteria, than those stated in Recommendation Recommendation ITU-R M.1638 [i.23]. (WRC-03)		
5.450B	In the frequency band 5 470 MHz to 5 650 MHz, stations in the radiolocation service, except ground-based radars used for meteorological purposes in the band 5 600 MHz to 5 650 MHz, shall not cause harmful interference to, nor claim protection from, radar systems in the maritime radionavigation service.(WRC-03)		
5.451	*Additional allocation:* in the United Kingdom, the band 5 470 MHz to 5 850 MHz is also allocated to the land mobile service on a secondary basis. The power limits specified in Nos. **21.2**, **21.3**, **21.4** and **21.5** shall apply in the band 5 725 MHz to 5 850 MHz.		
5.452	Between 5 600 MHz and 5 650 MHz, ground-based radars used for meteorological purposes are authorized to operate on a basis of equality with stations of the maritime radionavigation service.		
5.453	*Additional allocation:* in Saudi Arabia, Bahrain, Bangladesh, Brunei Darussalam, Cameroon, China, Congo (Rep. of the), Korea (Rep. of), Côte d'Ivoire, Egypt, the United Arab Emirates, Gabon, Guinea, Equatorial Guinea, India, Indonesia, Iran (Islamic Republic of), Iraq, Israel, the Libyan Arab Jamahiriya, Japan, Jordan, Kenya, Kuwait, Lebanon, Madagascar, Malaysia, Nigeria, Oman, Pakistan, the Philippines, Qatar, the Syrian Arab Republic, the Dem. People's Rep. of Korea, Singapore, Sri Lanka, Swaziland, Tanzania, Chad, Thailand, Togo, Viet Nam and Yemen, the band 5 650 MHz to 5 850 MHz is also allocated to the fixed and mobile services on a primary basis. In this case, the provisions of Resolution **229 (WRC-03)** do not apply. (WRC-03)		
5.454	*Different category of service:* in Azerbaijan, the Russian Federation, Georgia, Mongolia, Uzbekistan, Kyrgyzstan, Tajikistan and Turkmenistan, the allocation of the band 5 670 MHz to 5 725 MHz to the space research service is on a primary basis (see No. **5.33**). (WRC-03)		
5.455	*Additional allocation:* in Armenia, Azerbaijan, Belarus, Cuba, the Russian Federation, Georgia, Hungary, Kazakhstan, Latvia, Moldova, Mongolia, Uzbekistan, Kyrgyzstan, Tajikistan, Turkmenistan and Ukraine, the band 5 670 MHz to 5 850 MHz is also allocated to the fixed service on a primary basis. (WRC-03)		
5.456	*Additional allocation:* in Cameroon, the band 5 755 MHz to 5 850 MHz is also allocated to the fixed service on a primary basis. (WRC-03)		
5.457A	In the bands 5 925 MHz to 6 425 MHz and 14GHz to 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)		
5.457B	In the bands 5 925 MHz to 6 425 MHz and 14GHz to 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, the Libyan Arab Jamahiriya, Jordan, Kuwait, Morocco, Mauritania, Oman, Qatar, the Syrian Arab Republic, 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-03)		

C.2 Specific coexistence studies

Based on the existing coexistence investigation mainly the following service has been identified as a possible victim system for specific consideration:

- CEN DSRC Tolling: 5 795 MHz to 5 815 MHz:
    - Update of Report 101 needed with new out-of-band limits and Duty Cycle restriction considerations.

Annex D: Coexistence with CEN DSRC tolling systems

D.1 Victim System technical overview

ECC Decision (02)01 designates the frequency band 5 795 to 5 805 MHz, with possible extension to 5 815 MHz, for RTTT road tolling applications. The band 5 795 MHz to 5 805 MHz is for use by initial road-to-vehicle systems, in particular road toll systems, with an additional sub-band, 5 805 MHz to 5 815 MHz, to be used on a national basis to meet the requirements of multi-lane road junctions.

Although there is at least 40 MHz of guard band between ITS and RTTT road tolling systems, the potentially close vicinity in the deployment of both systems may raise some coexistence problems.

Three main types of potential problems have been identified:

- interference from the RTTT road tolling Road-side Unit (RSU) on the ITS;
- interference from the ITS on the RTTT road tolling RSU;
- impact from the ITS on the RTTT road tolling On-Board Unit (OBU).

The interference from RTTT road tolling Road-side unit on the ITS systems has been investigated in ECC Report 101 [i.9] and has shown no harmful interference potential.

D.2 Parameters and protection criteria of RTTT road tolling systems

D.2.1 Introduction and overview

The regulatory parameters (maximum power levels) for RTTT road tolling systems (TTT for road tolling purposes) are given in Annex 5 of ERC Recommendation 70-03 [i.26]. The RTTT road tolling system parameters used in the present document are taken from the EN 300 674 [i.4] developed by ETSI and the EN 12253 [i.28] developed by CENELEC. It should be noted that the EN 300 674 [i.4] deals with both Road Side Units (RSU) and On-Board Units (OBU) and is divided in two parts, the part 1 providing general characteristics and test methods, the part 2 containing the essential requirements under article 3.2 of the R&TTE Directive.

The technical requirements of the RTTT DSRC road tolling devices are split into two categories:

1) the Road Side Unit is an active device with a high emission level and very high receiver sensitivity value which is higher than the typical values of mobile ITS devices;

2) the On Board Unit is a passive device with reduced level of emission (back-scattering uplink communication) and poor level of sensitivity (downlink communication).

In the following clause the main operational and technical characteristics of the investigated CEN DSRC tolling systems are depicted. The focus is on the deployment scenarios and the critical operational conditions where a potential interference from ITS-G5 systems might occur. A typical tolling zone geometry is depicted in figure D.1 for a two lane scenario. The interference from an ITS-G5 system can only occur during the transaction between the Road Side Unit (RSU) and the On Board Unit (OBU) in the tolling zone. Another possible interference effect could be the wake up of the OBU from the power save mode initiated by ITS-G5 signals.

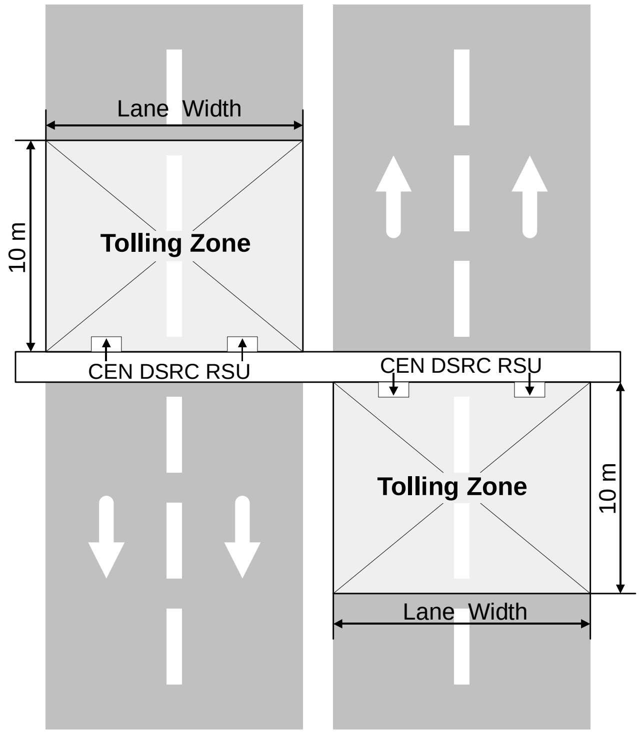

Figure D.1: Typical tolling zone geometries for a two lane free flow scenario

Three main tolling station applications need to be differentiated due their different operational conditions:

- Free-Flow tolling stations and enforcement stations with a maximum of 6 parallel lanes (typical 3 lanes to 4 lanes in each traffic direction). Here the speed of the mobiles can be high. No specific speed limit is given during the tolling operation, see figure D.2.
- Toll plazas with an automatic barrier with up to 40 parallel lanes (Typical around 10 lanes to 20 lanes in each traffic direction). Here the vehicular speed is very limited.
- Toll plazas with automatic lanes (reduced speed) with up to 40 parallel lanes (typical around 1 lane to 10 lanes in each traffic direction). Here the speed limit is in the range of 30 km/h, see figure D.3.

Figure D.2: Typical free-flow installation with three lanes

Figure D.3: Typical toll plaza with an automatic barrier (left) and automatic lanes (right)

D.2.2 Technical Characteristics of the Road side Unit (RSU)

D.2.2.1 RF characteristics

Detailed characteristics are defined in table D.1.

Table D.1: Parameters of a typical RSU

DSRC Road Side Unit (RSU)	Value	Units
Receiver bandwidth	500	kHz
Receiver sensitivity (at the receiver input)	-104	dBm
Antenna gain bore sight	13	dBi
Antenna gain outside RSU active angle	-2	dBi
Antenna polarization	LHCP	
cross-polar discrimination, ellipticity of polarization	10	dB
TX output power level, EIRP	33	dBm
RSU mounting height above ground	2,5 to 7,5	m
Protection criterion (S/I)	6	dB
TX Frequency/Bandwidth	500 kHz	

D.2.2.2 Antenna

The RSU antenna is tilted downside for the interrogation of the onboard units. Outside of the main beam the antenna has reduced gain by a factor of around -15 dB. The typical main beam e.i.r.p. is 33 dBm leading to an e.i.r.p of around 18 dBm outside of the main beam. A typical setup is depicted in figure D.4. A large part of the 10 m tolling zone is covered by the main beam.

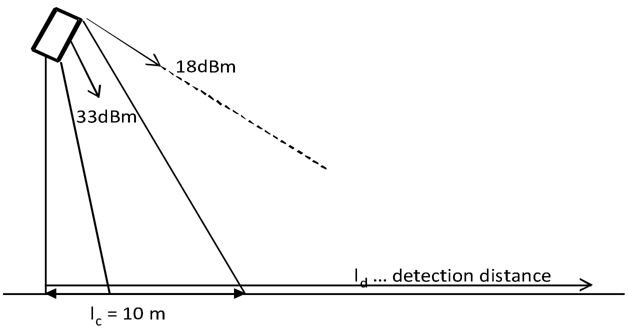

Figure D.4: Typical Antenna characteristics of a RSU antenna

In a multilane set up with several parallel lanes a single RSU will cover more than a single lane. This leads to an overlap between two adjacent RSUs. By doing so, a better coverage can be guaranteed.

D.2.3 Technical Characteristics of the Onboard Unit (OBU)

D.2.3.1 RF characteristics

Detailed characteristics are defined in table D.2 (from TR 102 654 [i.29]).

Table D.2: Parameters of a typical OBU

DSRC On Board Unit (OBU)	Value	Units
OBU sensitivity (typical, at antenna front)	-60 to -50	dBm
Wakeup sensitivity (at antenna front)	-60 to -43	dBm
Maximum re-radiated sub-carrier e.i.r.p. for -35°≤ θ ≤ 35° azimuth and elevation:	-14	dBm
Antenna polarization	LHCP	
cross-polar discrimination, ellipticity of polarization	6	dB
Car windscreen loss	3	dB
OBU mounting height above ground	1 to 2,2	m
Protection criterion (S/I)	10	dB
RX bandwidth	500	MHz
TX bandwidth	500	kHz
TX Frequency	See clause 5.1 [i.29]	

D.2.3.2 Antenna

The typical antenna pattern of an OBU is given in figure D.5. This antenna pattern is the standalone OBU antenna pattern. The effective antenna patterns including the car attenuations will be presented in the result section of the present document.

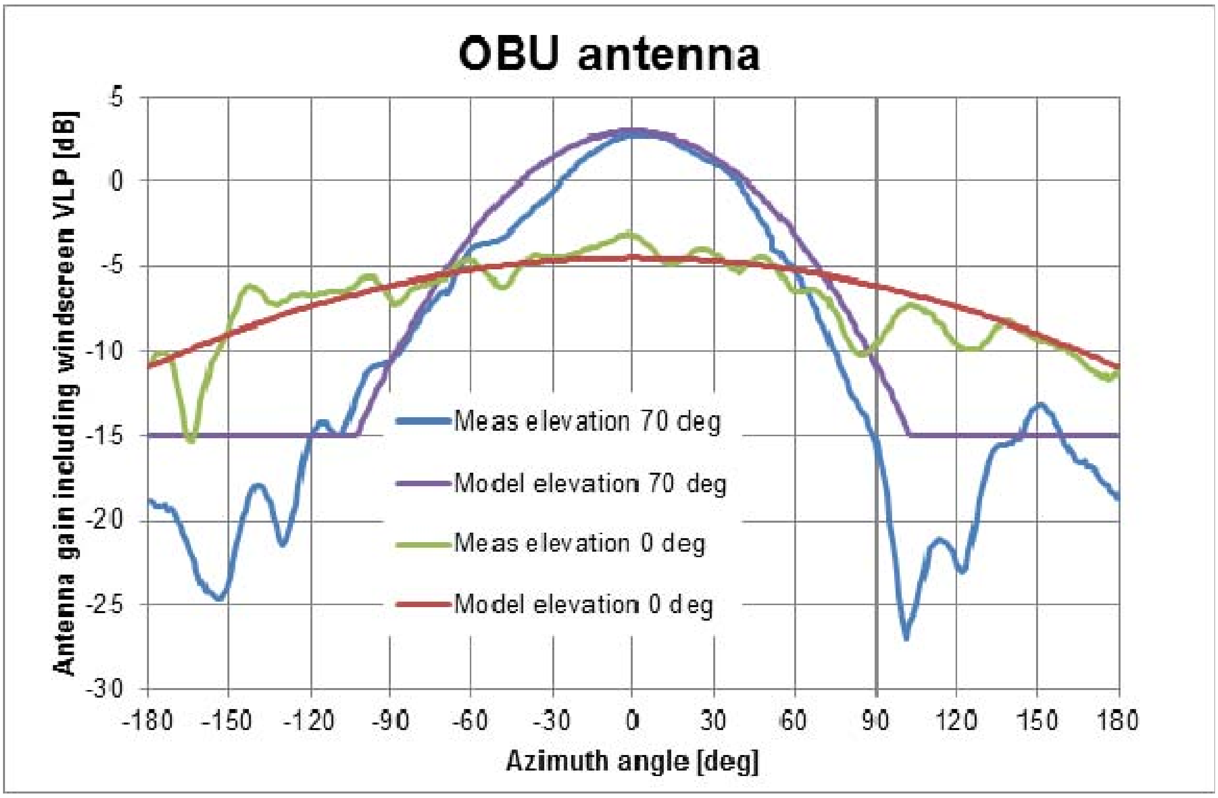

Figure D.5: Typical isolated antenna pattern of a CEN DSRC On Board unit (OBU)

D.2.4 Protocol Layer

The basics of the timing of a CEN DSRC transaction are defined by EN 12795 [i.25]. Timing details are application specific and different for each toll operator and toll station type (see clause D.2.1). Additionally the OBU type can have an influence on the timing behaviour (e.g. the late response procedure as defined in EN 13372 [i.27]).

The timing behaviour of a CEN DSRC transaction can be exploited to optimize the coexistence properties taking into account the duty cycle restrictions defined in the ITS G5 systems. The interference mitigation effect of a duty cycle restriction has been investigated and evaluated in [i.30].

D.3 Potential mitigation factors and methods

D.3.1 Introduction

In [i.17] and [i.30] specific scenarios have been identified in which harmful interference will occur from mobile ITS stations towards CEN DSRC tolling applications. These scenarios need to be covered with specific mitigation methods and techniques. Several possible mitigation factors have already been identified in [i.17] and [i.30]. In the case of a limited density of mobile ITS stations with limited power levels and/or limited duty cycles no harmful interference will occur. Nevertheless, under high density conditions and/or new application requirements harmful interference might occur.

In the following clauses some possible mitigation factors and methods are presented as a potential solution for these interference scenarios. In coexistence investigations the detailed parameters of the mitigation factors like duty cycle, power limitations and mitigation distances need to be fixed.

D.3.2 Bi-modal operation

In [i.17] it has been shown that RTTT road tolling stations require protection from transmissions of mobile ITS stations in close vicinity of these stations. In-band power reduction to maximum 10 dBm and out-of-band power levels of maximum -65 dBm/MHz, except for low duty cycle transmission packets at higher power will protect the RTTT road tolling station from harmful interference under all conditions.

If 10 dBm is considered to make certain applications difficult to use and/or -65 dBm is considered to be too difficult to implement at full power of +33 dBm, two different modes of operation are proposed to be used, namely Normal mode and Restricted mode:

- Normal mode would allow for: maximum +33 dBm in band and -30 dBm/MHz out-of-band power.
- Restricted mode would allow for: maximum +10 dBm in band and -65 dBm/MHz out-of-band in the band 5 795 MHz to 5 815 MHz.

The restricted mode could also be a limited duty cycle of the ITS operation [i.30].

When in normal mode it is then mandatory for the ITS station to switch to Restricted mode when it receives an ITS message with parameter *Protected zone* and the mobile ITS station density and the duty cycle would require an additional level of protection.

The obligation to transmit a message should preferably be put on the interferer, the ITS station, which would be obliged to do this after detection of an RTTT road tolling station.

D.3.3 Duty cycle restrictions

The investigations in [i.30] have been focused on the potential interference into the CEN DSRC system. In [i.30] it has been shown that a limited number of active mobile ITS station with a certain duty cycle restriction in the vicinity of a CEN DSRC station will not lead to a harmful interference with the road tolling operation. The investigations in [i.30] have been focused on the potential interference into OBU of the CEN DSRC system. Mitigation factors (duty cycle, mitigation distances) to protect the road side units (RSU) using the defined duty cycle restrictions in combination with a power limitations need to be defined.

Restrictions already included in the ETSI specification should be taken into account including the message generation rate based on the vehicular speed.

However, important applications may require much higher duty cycles than outlined in clause 6.4. In a number of research projects (PATH 1994, CHAUFFEUR 1996, CHAUFFEUR II 2000, KONVOI 2005, JARI 2008, SARTRE 2009, GCDC 2011, IQFleet 2011, RelCommH 2013) platooning heavy vehicles has been demonstrated to save large amounts of fuel, but the platooning application requires up to 50 Hz packet rate over ITS G5. Such applications may not be possible if today's duty cycles are regulated to be the maximum allowed.

Therefore a Restricted mode with reduced output power level and reduced out of band emission will be necessary for such applications.

Annex E:
Bibliography

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History

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