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Technical Report

Electromagnetic compatibility and Radio spectrum Matters (ERM); Intelligent Transport Systems (ITS); Part 1: Technical characteristics for pan-European harmonized communications equipment operating in the 5 GHz frequency range and intended for critical road-safety applications; System Reference Document

Reference

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Foreword

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

The present document is part 1 of a multi-part deliverable covering Intelligent Transportation System (ITS) as identified below:

Part 1: "Technical characteristics for pan-European harmonized communications equipment operating in the 5 GHz frequency range and intended for critical road-safety applications; System Reference Document";

Part 2: "Technical characteristics for protected communications equipment operating in the 5 GHz frequency range on a National basis intended for road-safety and traffic-management applications; System Reference Document";

Part 3: "Technical characteristics for non-protected communications equipment operating in the 5,470 GHz to 5,725 GHz frequency range; System Reference Document".

Introduction

The report 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 past the severity of accident effects could be significantly reduced by passive safety systems, e.g. the airbag. New active safety systems which are based on car-to-car communications, or in some cases, car-to-infrastructure communications, will not only provide for further reduction of the accident severity but also for the decrease of the number of road accidents. The main objective of the introduction of car-to-car communication is to reduce the number and severity of automobile accidents.

The need for ITS data communication and a suitable frequency designation has been recognized for several years. Car-to-car communication systems have been a topic in research since the second half of the eighties. Although many technical key challenges were solved in a number of research activities, car-to-car communication systems have not been implemented in our vehicles so far. Reasons for this are the missing of an appropriate frequency band which grants effective protection for road safety applications and the lack of commercially available cheap radio hardware. With the WLAN (IEEE 802.11) technology, now a radio technology is available as a mass product which fulfils technical as well as business requirements.

Microwave systems in the 5 GHz range can offer communications with a high data rate, ranges up to 1 000 metres, low weather-dependence, and global compatibility and interoperability.

Europe was pioneering the use of microwave communication with the RTTT DSRC system at 5,8 GHz.

Part 1 is dedicated to critical road safety applications requiring low latency and little protocol overhead, especially in case of communications between vehicles. The proposed frequency allocation considers the minimum bandwidth required for pan-European usage. Part 2 can be considered as an extension of part 1 providing additional communication channels and performance, where there is no urgent need for extremely low latency, such that usage of channels can be negotiated/identified based on different national availability. The additional functionality related to part 2 is flexible networking using IPv6 protocols. The applications considered for part 3 are not safety related. It is highly desirable that the allocation of channels as described in the three parts of this muti-part deliverable is effected such, that the channels are contiguous, or at least nearby. Clause B.3 describes complementary application and system standards.

In the USA the allocation of a frequency band for car-to-car and car-to-infrastructure communications was the initial impulse to initiate the development and standardization of radio systems adapted to US traffic, road structure and regulations.

eSafety is a joint initiative of the European Commission (DG Enterprise and DG Information Society), industry and other stakeholders and aims to accelerate the development, deployment and use of Intelligent Integrated Safety Systems, that use information and communication technologies in intelligent solutions, in order to increase road safety and reduce the number of accidents on Europe's roads. The eSafety work is also supported by the European Car-to-Car Communication Consortium (C2C-CC), which comprises the major European car manufacturers, OEMs and suppliers.

The targets of the joint eSafety initiative [1] from the European Commission, industry and other stakeholders are to reduce road fatalities by 50 % up to 2010, improving efficiency of road traffic, and promoting intelligent vehicle safety systems.

In order to help meet the eSafety targets, a European frequency designation offering a certain degree of effectively protected spectrum for high-reliability road safety services is requested. There are several current and proposed EU projects under the eSafety initiative that depend on this designation, e.g. Prevent/WILLWARN, CVIS, SAFESPOT, ADASE, CarTALK, etc. [1].

1 Scope

The present document describes traffic telematics applications with the primary intention of reducing the number and severity of traffic accidents. It defines the spectrum usage requirements and protection parameters for communications equipment:

- Primarily vehicle to vehicle.
- Vehicle to roadside/infrastructure.

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 (annex A).
- Technical information (annex B).
- Expected compatibility issues (annex C).

2 References

For the purposes of this Technical Report (TR), the following references apply:

[1] The *e*Safety Working Group (November 2002): "Final report of the eSafety Working Group on Road Safety".

NOTE: http://europa.eu.int/information_society/activities/esafety/esafety_before_2005/esafety_2002/index_en.htm.

[2] CEPT ECC/DEC/(04)08 of 9 July 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).

[3] 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".

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

NOTE: Lisbon January 2002 - Dublin 2003 - Turkey 2004 - Copenhagen 2004.

[5] 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".

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

[7] IEEE 802.11p: "Wireless Access for Vehicular Environments - Draft standard".

[8] 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".

[9] ITU-R Recommendation 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".

[10] ITU-R Recommendation 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".

[11] ITU-R Recommendation 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".

3 Definitions, symbols and abbreviations

3.1 Definitions

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

roadside unit: radio access point usually fixed as part of the road infrastructure

NOTE: Includes localized transmitters or receivers or both functions integrated into one unit.

roadside-to-vehicle communications: communications between the roadside and the vehicle

NOTE: Includes vehicle-to roadside communications.

roadside: includes:

- single RSUs operating in a stand-alone fashion;
- or a group of RSUs connected together by an appropriate infrastructure, which may include an information network;
- or a single RSU connected to an information network.

WAVE: name of IEEE 802.11p group and technology

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:

AFC	Automatic Fee Collection
BPSK	Binary Phase-Shift Keyed
BW	BandWidth
C2C	Car-to-Car
C2C-CC	Car-to-Car Communication Consortium
C2R	Car-to-Roadside
CALM M5	CALM for the 5GHz Microwave range
CALM	Continuous Air interface Long and Medium range
CEN	European Committee for Standardization
COTS	Commercial Off The Shelf
dB	deciBel
DSRC	Dedicated Short Range Communication
e.i.r.p.	equivalent isotropic radiated power
GaAs	Gallium Arsenide
GI	Guard Interval
IEEE	Institution of Electrical and Electronic Engineers
ISM	Industrial, Scientific and Medical
ISO	International Standards Organisation
IVC	Inter-Vehicle Communications
IVU	In-Vehicle Unit (also called On-Board Unit or On-Board Equipment)
MAC	Medium Access Control
OBU	OnBoard Unit
OEM	Original Equipment Manufacturer
ppm	part per million
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase-Shift Keyed
RSU	Road-Side Unit
RTTT	Road Transport and Traffic Telematics
RVC	Roadside-to-Vehicle Communications
SRD	Short Range Device
SRDoc	System Reference Document
TBD	To Be Determined
U-NII	Unlicensed National Information Infrastructure (USA)
WAVE	Wireless Access in Vehicular Environments
WLAN	Wireless Local Area Network

4 Executive summary

4.1 Status of the system reference document

ERM RM#29 decided to forward working version 1.1.1_0.0.6 of the present preliminary draft system reference document to ECC WG FM to provide preliminary information about ITS to the ECC. RM#29 also decided to split the document into a 3-parts system reference document in order to clarify the individual requirements for the different ITS applications.

Working version 1.1.1_0.0.7 was prepared by ERM TG37, following the decision by ERM RM#29 to split the former draft SRDoc on ITS into a 3-part-deliverable. A short consultation through ERM RM resulted in the document (working version 1.1.1_0.0.8), which was forwarded as preliminary draft document to ECC-SRD MG (April 2005 meeting).

Working version v1.1.1_2.0.10 of the document was discussed and approved by ERM RM in May 2005 subject to validation by the ERM-TG37 meeting to be held in the week of 9 May 2005.

Working version v.1.1.1_2.0.11 of the document is the result of the ERM-TG37 meeting held on 12 and 13 May 2005.

The present document (based on working version v1.1.1_2.0.12) includes the proposed revisions by ERM-TG37 with revision marks. Due to time constraints these have not been presented to ERM RM for approval. The present document is forwarded to CEPT for consideration and to ERM#26 for approval for publication. ERM#26 will be asked to consider the proposed changes before approval of the present document for publication.

4.2 Technical issues

4.2.1 Spectrum requirement and justification

The spectrum requirement includes 2 × 10 MHz of bandwidth for high-priority safety related ITS services and applications to be available on a pan-European basis.

The 2 × 10 MHz consist of one channel for control purposes and for road safety applications and one additional channel for road safety applications only. Adjacent channels are needed to allow simultaneous reception in a frequency band with protection to avoid any confusion on where to transmit in an emergency situation.

Tasks of the control channel are for example the compilation of neighbourhood tables or the announcement of services provided by other channels as described in part 2 and 3 of the present technical report. Control messages are very short messages which will require only a very limited part of the channel capacity.

These ITS services need an effective protection to avoid delays caused by open contention for channel access and interference with undetectable channel usage in a highly dynamic network environment. This protection cannot be found in the 5 GHz WLAN frequency bands or in the 5,8 GHz ISM frequency band.

4.3 Market information

The recent increase in maturity of WLAN technology and availability of high-performance, low-cost products have resulted in a rise in the commercial interest in practical systems for transport telematics applications.

One common characteristic of road safety applications based on car-to-car communication is the fact that a certain penetration of equipped cars is required. A system will not be accepted, if there is no benefit right from the beginning of operation. For example if a driver runs 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 market introduction applications are required, which offer immediate benefit to the car holders and drivers to overcome the introduction phase characterized by low penetration rates. A particularly suitable solution would be the provision of WLAN hotspot access with the same communication system. Typical applications for hotspot access at gas stations are downloading of information about restaurants, sight seeing points or traffic data along the anticipated route. Wireless media file exchange at home and wireless diagnosis at workshops are further examples of deployment applications.

Road safety related ITS applications and WLAN hotspot access complement one another most skilfully.

Further information is provided in annex A.

4.4 Technical system description

This information is provided in annex B.

5 Current regulations

There is no current regulation for high-priority safety related ITS services requiring protection in Europe.

6 Proposed regulation

It is proposed that the ECC identifies spectrum for ITS services and applications in the 5 GHz range.

The spectrum requirement consists of 2 × 10 MHz effectively protected bandwidth for ITS services organized in two channels which is prioritized for critical road safety applications. This spectrum is required to be available in contiguous channels on a pan-European basis under one common European frequency designation.

The required 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.

The assigned spectrum in the USA is given in table A.1.1.1.1. The upper boundary of the current frequency assignments for safety services and applications in the USA is 5,925 GHz. As a consequence of the USA assignment and driven by the protection requirements, ETSI prefers the use of frequencies for ITS in the frequency range above the 5,8 GHz ISM band from 5,875 GHz to 5,925 GHz.

One advantage of this solution would be the harmonization with the FCC regulations [3], especially by using the same frequency range for the control channel (5,885 GHz to 5,895 GHz) and the contiguous 10 MHz for a second safety channel. Active safety systems including car-to-car communication will be highly integrated in the vehicles and the possibility to use worldwide the same communication hardware is for cost reasons an important factor of the system introduction. Additionally the proposed frequency range is close to the WLAN frequencies in the 5 GHz range and allows therefore the provision of additional non-safety related applications in the 5 GHz WLAN-frequencies and which is an important factor for the system introduction as explained in clause 4.3 of the present document.

6.1 Requested licensing conditions

The spectrum for safety related ITS services must 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.

6.2 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.

7 Main conclusions

7.1 Business importance

The need for ITS data communication and a suitable frequency designation has been recognized for several years. Car-to-car communication systems have been a topic in research since the second half of the eighties. Although many technical key challenges were solved in a number of research activities, car-to-car communication systems have not been implemented in our vehicles so far. Reasons for this are the missing of an appropriate frequency band which grants effective protection for road safety applications and the lack of commercially available cheap radio hardware. With the WLAN (IEEE 802.11) technology now a radio technology is available as a mass product which fulfils technical as well as business requirements.

7.2 Expected timing for ITS to market in Europe

It is intended to place commercial ITS products on the market (i.e. built in cars) by 2008. Under the assumption that it would take approximately 2 years for planning and preparing the incorporation of ITS in cars, a definite frequency decision from CEPT is required before the end of 2006 to support adequate and secure planning efforts.

7.3 Expected ECC and ETSI actions

ETSI requests the ECC to perform the following actions:

- Investigate and identify suitable spectrum for ITS services and applications in (or close to) the 5 GHz frequency range. As part of the ECC action, ECC should consider the preferred option in clause 6 of the present document, i.e. use of 2 × 10 MHz for pan-European usage of ITS for effectively protected services and applications in the frequency range above the 5,8 GHz ISM band: from 5,875 GHz to 5,925 GHz. Furthermore, the most preferred frequency for the control channel would be in the range from 5,885 GHz to 5,895 GHz to allow for technical solutions which are available in other regions as well.

- Perform necessary compatibility studies in the process of identifying the most suitable spectrum for ITS in Europe.

- Develop and adopt an CEPT ECC Decision that would allow for ITS to be introduced in the European markets as of the beginning of 2008. A frequency decision from CEPT is required before the end of 2006 to support the eSafety initiative and enable adequate and secure planning efforts by authorities and industry.

ETSI actions:

- ETSI intends to develop standards for ITS in ERM TG37 to cover the technical operational specifications and measurement requirements for ITS devices that are the subject of the present document.

- Co-existence issues between ITS (inter-vehicle communication units as interferer) and RTTT DSRC (5,795 -5,815 GHz) on-board units (as victim) need to be investigated. ETSI ERM TG37 members intend to address this concern by conducting measurements to investigate the situation.

Annex A: Market information

A.1 Summary of application types

Lists of applications for Vehicle-Vehicle and Vehicle-Roadside Communication have been investigated by various projects and groups, and the number of applications is very high. Some lists are presented in clause A.1.1 below.

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.

A.1.1 Situation outside Europe

A.1.1.1 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 development on these issues. There is a US FCC regulation, published on August 3, 2004 [3].

The assigned spectrum for the Dedicated Short Range Communications Service in North America is shown in the table A.1.1.1.1. Canada has similar assignments with minor differences.

Table A.1.1.1.1: 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 - Ch. 178).
- Additionally also the channel 5,855 GHz to 5,865 GHz (Ch 172) is requested to be assigned only for safety applications.
- There are 2 couples of adjacent channels, which may be used as one channel with a bandwidth of 20 MHz.

A.1.1.2 Far East, Australia, South America

The situation in Japan and Korea is more similar to Europe. Both of these countries have adopted national DSRC systems in the 5,8 GHz range and have large investments on deployment of these.

There are some new spectrum allocations in particular in Japan that can be used for this technology. IEEE 802.11j [5] going from 4,9 GHz to 5,1 GHz uses similar power and channelization bandwidth to IEEE 802.11p [7], and can therefore easily be used for these services.

China is interested in the CALM M5 and IEEE 802.11p [7] 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, and has large scale national deployment of these systems. There is no known spectrum planning on CALM M5/WAVE technology in Australia.

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.1.2 Examples of applications

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 of ITS has invested a lot of work in the analysis of the accident reduction by car-to-car communications.

A.1.2.1 List of safety related applications

The following table shows an extraction of a list of safety-related ITS applications.

Table A.1.2.1.1: 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.
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.

Application	Description
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.

A.1.2.2 Specific applications

Figures A.1.2.2.1.1, A.1.2.2.2.1 and A.1.2.2.3.1 explain some of the application examples.

A.1.2.2.1 Workzone warning

- 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.

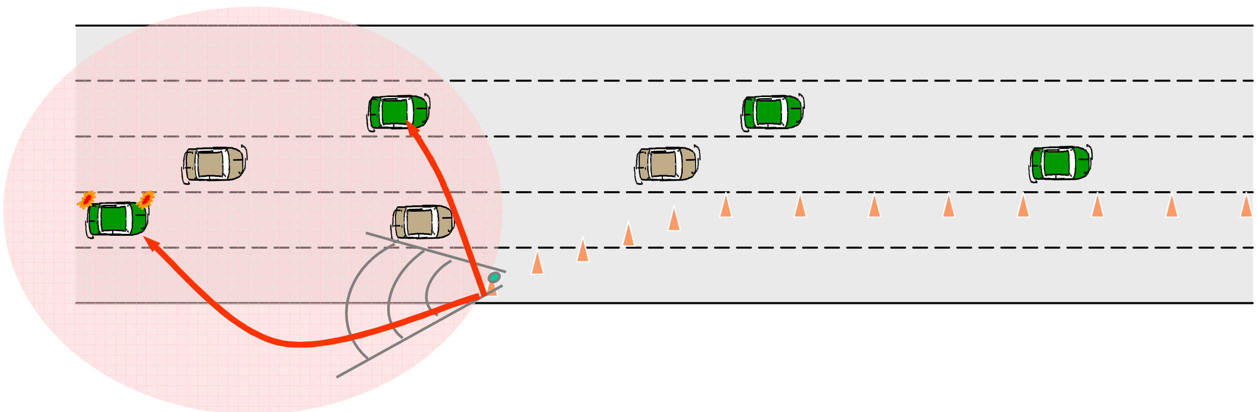

Figure A.1.2.2.1.1: Workzone warning

A.1.2.2.2 Emergency vehicle approaching

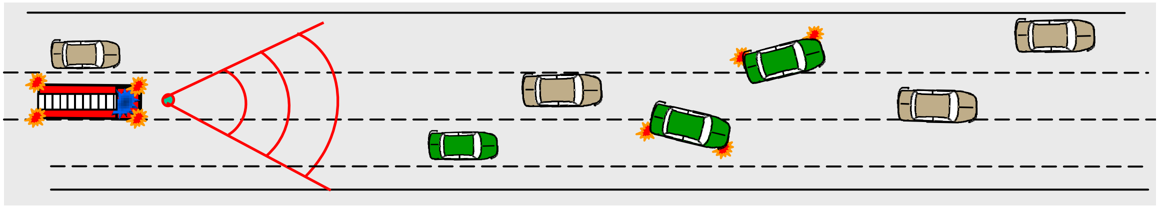

Figure A.1.2.2.2.1: Emergency vehicle approaching

A.1.2.2.3 Hazard warning with car-to-car communication

- 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.

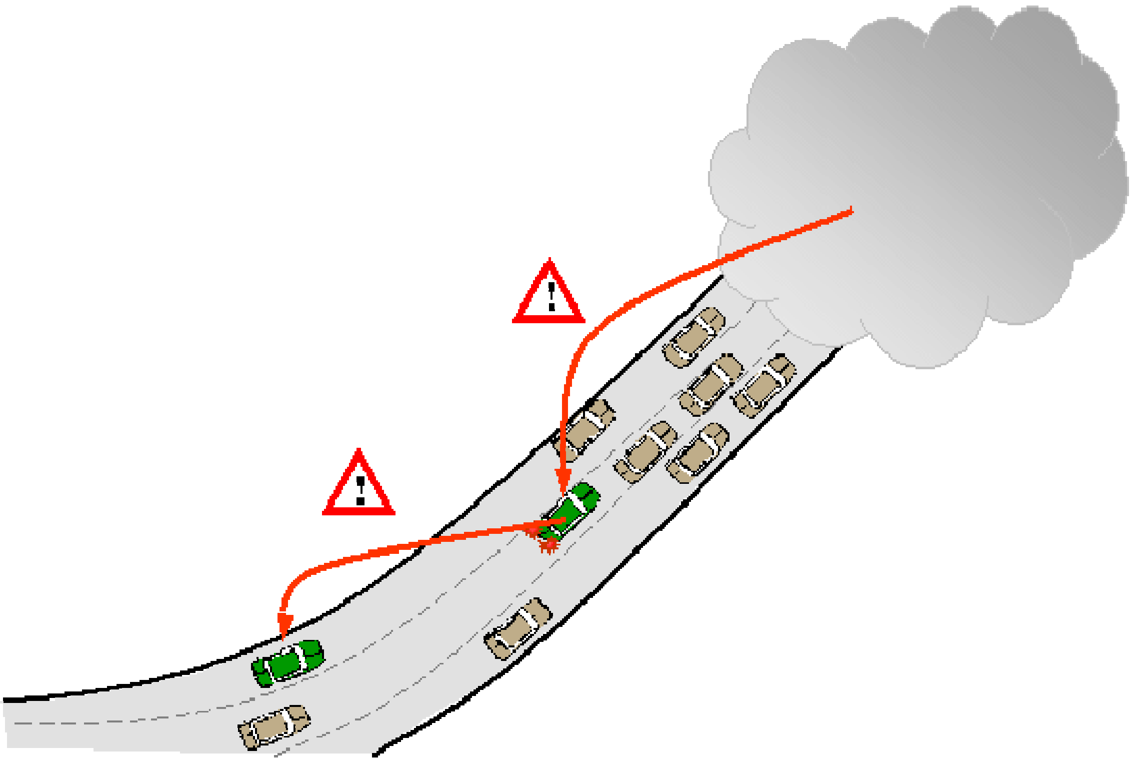

Figure A.1.2.2.3.1: Hazard warning

A.2 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. A list of deployment applications will be given in part 3 of this multi-part deliverable.

For the deployment applications, the C2C-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 must be such that an evolutionary roll-out is possible, with backward-compatibility so as not adversely to affect early enterers.

A.3 Traffic evaluation

The functionality required of a high data rate communication system for next-generation transport telematics is that it should support C2C-and C2R-communication in a dynamic traffic environment, in a range of weather conditions, and with communication ranges extending to several hundred metres. It must 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 scenario.

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 in congestion situations.

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

c) The average conveyed ITS message duration can be assumed to be approximately 1 millisecond.

Annex B: Technical information

B.1 Technical description

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.

B.1.1 IEEE 802.11p

The basis for this technology is a variant of the IEEE 802.11a [6] and IEEE 802.11j [5] standards.

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 [6], 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. Currently, IEEE 802.11p [7] is being defined (known as WAVE – Wireless Access in the Vehicular Environment) with C2C and C2R connectivity for 5,9 GHz systems in view. This is a variant of 802.11a [6] 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 must be provided to allow interoperability with the CALM architecture.

International compatibility is important, and ETSI and ISO already have a co-operation to further this requirement.

The IEEE 802.11 Task Group P has accepted the general principles of regulatory domain updates, and the IEEE 802.11p [7] draft is being brought in line with 802.11j [5] on most points of interest for non-American domains. This work is being done in co-operation with ISO TC204/WG16, ETSI ERM TG37 and C2C-CC who are particularly considering the characteristics of European traffic, roads and regulations.

B.1.2 Draft system parameters

Table B.1.2.1: Draft system parameters (not exhaustive)

Parameter	Value	Comments
Frequency stability	1ppm	This figure takes account of the frequency tolerance allowed by IEEE 802.11a [6], 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

Parameter	Value	Comments
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 802.11a [6] and p [7].
Data rates	3/4.5 /6/9/ 12/18 /24/27 Mbit/s	This is the standard set within IEEE 802.11a [6], j [5] and p [7]. As an option two channels may be combined to produce double data rates (up to 54 Mbit/s). Default data rate is 6Mbit/s.
Channel Bandwidth	10 MHz, option 20 MHz	This is the standard set within EEE 802.11a [6], j [5] and p [7].
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.1.2.2: 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.1.2.1.					

B.2 Technical justification for spectrum

The public 5 GHz channels for WLAN IEEE 802.11a [6] and IEEE 802.11h [8] (5 150 MHz to 5 350 MHz and 5 470 MHz to 5 725 MHz), as identified in ECC/DEC/(04)08 [2], 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 [6] and IEEE 802.11h [8] 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 implements a DFS mechanism to avoid co-channel operation with radar systems. DFS requires to silence 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.
- Note that the requested spectrum for ITS safety applications is allocated in adjacent pairs of 2 × 10 MHz. Thus, these channels can be joined to obtain a single 20 MHz channel for certain situations.

Introduction

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 we assume 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.2.1: 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 [6] using a BW of 10 MHz. The link budget calculated here assumes data rates and minimum receiver sensitivities shown in table B.2.1. 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}.

Fresnel zone

A principal topic for the calculation of a link budget is to choose a proper path loss model. To this end, it has to be verified if clearance of the first Fresnel zone can be expected. The radius of the first Fresnel zone in the middle between sender and receiver is given by:

$$r = \sqrt{\frac{d\lambda}{4}}$$

where: d is the distance and λ is the carrier wave length. An illustration is shown in figure B.2.1. For d = 1 000 m and λ = 5 cm, we obtain r = 3,56 m. Thus, for typical vehicular-to-vehicular communication environments we cannot expect clearance of the first Fresnel zone. The antennas mounted on a car are much closer to the ground and obstacles can further obstruct the first Fresnel zone. Therefore, the link budget has to be calculated for line-of-sight communication with severely destructed first Fresnel zone. For this situation it is well known from mobile communications that the path loss coefficient is in the range $n \approx 2,5 \ldots 3$ (instead of $n = 2$ for free space transmissions). For the link budget calculations we assume $n = 2,7$.

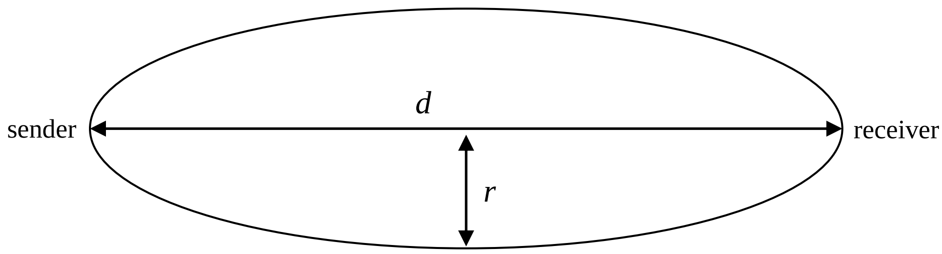

Figure B.2.1: Illustration of the first Fresnel zone

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.2.2. Comparing P_e with the minimum receive sensitivities in table B.2.1, 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 [6] 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.

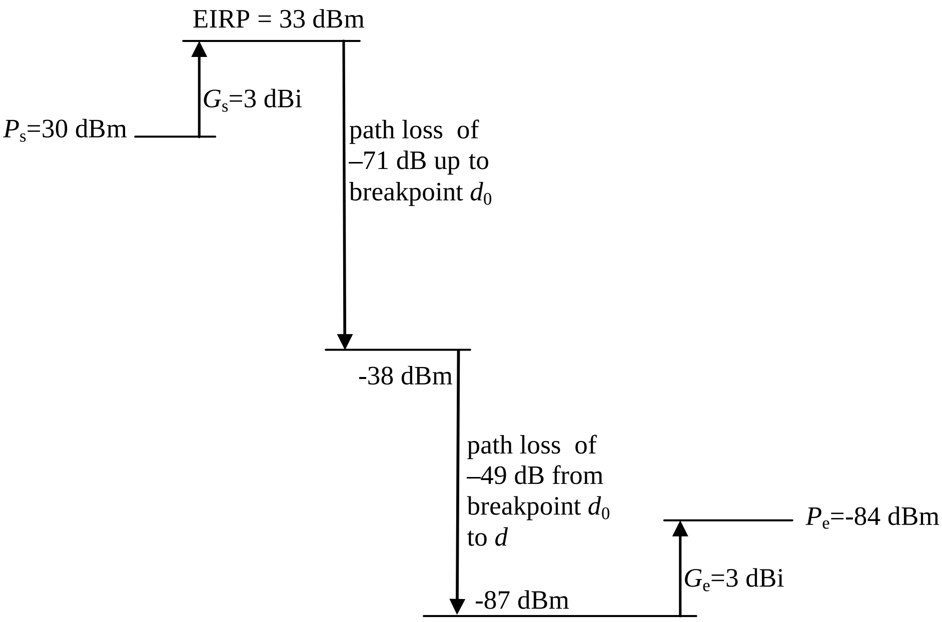

Figure B.2.2: Illustration of the link budget calculation

B.3 Information on current version of relevant standards

Basic parameters and protocols for high-reliability road safety services are being developed as a co-operation between ETSI ERM TG37, ISO TC204 WG16 (CALM M5), C2C-CC and IEEE 802.11p (WAVE) [7].

The C2C-CC is working out specifications taking into account European regulations, infrastructures, driving behaviour and government policies. Standards will be produced for the communication system and for the road safety applications to ensure interoperability between all cars.

The ISO standards group TC204 WG16.1 has prepared a specification for an architecture which will link applications to an appropriate bearer of a set of bearers, depending on what each has to offer at a given time in a given situation. It is recognized that all bearers cannot support all applications, and that there will be circumstances which favour one over another.

Annex C: Expected compatibility issues

C.1 Coexistence studies

Coexistence studies with existing radio services in the 5 GHz range are needed. 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.

Frequency band (MHz)	ITU Radio Regulations Region 1 allocation to services	European Common Allocation [4]	Utilization in ECA Table [4]
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

Frequency band (MHz)	ITU Radio Regulations Region 1 allocation to services	European Common Allocation [4]	Utilization in ECA Table [4]
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
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

Frequency band (MHz)	ITU Radio Regulations Region 1 allocation to services	European Common Allocation [4]	Utilization in ECA Table [4]
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
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

Frequency band (MHz)	ITU Radio Regulations Region 1 allocation to services	European Common Allocation [4]	Utilization in ECA Table [4]
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 (R) 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 [4]	Utilization in ECA Table [4]
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)		

Frequency band (MHz)	ITU Radio Regulations Region 1 allocation to services	European Common Allocation [4]	Utilization in ECA Table [4]
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 ITU-R Recommendation F.1613 [9]. 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 ITU-R Recommendation M.1638 [10] and ITU-R Recommendation SA.1632 [11]. (WRC-03)		
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 radiodetermination 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 ITU-R Recommendation M.1638 [10]. (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)		

Frequency band (MHz)	ITU Radio Regulations Region 1 allocation to services	European Common Allocation [4]	Utilization in ECA Table [4]
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)		

Co-existence issues between ITS (inter-vehicle communication units as interferer) and RTTT DSRC (5,795 GHz-5,815 GHz) on-board units (as victim) need to be investigated. It is intended that ETSI ERM TG37 members will address this concern by conducting measurements to investigate the situation. Some of the frequencies in the 5 GHz band are in use by military radar applications.

C.2 Current ITU allocations

In the ITU-R, WP8A is responsible for ITS. There are some recommendations related to the 5GHz band, mostly reflecting current RTTT DSRC allocations in Europe and Japan.

In the last World Radio Conference (WRC-03), the issue of a global allocation for ITS safety applications was brought up by Canada. This proposal received support from US and also from Europe. The proposal was withdrawn due to heavy opposition from some Asian countries.

C.3 Sharing issues

Some ITS services are intended for critical road safety applications, and it is therefore important to find spectrum assignments with minimum interference from other services.

As a consequence, these ITS services and applications can not be operated inside spectrum where e.g. COTS WLAN equipment can tune directly, i.e. not inside the U-NII bands (includes 5,250 to 5,350 GHz and 5,725 to 5,825 GHz) in the USA, or inside the European ISM frequency band.

Concerning interference to RTTT DSRC it is important to note that DSRC Onboard units (OBUs) can cope with statistical random interference. However, systematic interference from inter-vehicle ITS could cause unacceptable interference and could also cause premature end-of-life of the OBUs due to OBU battery drain, if both kind of equipment are installed in the same vehicle. A potential solution under study to avoid this could be the integration of the RTTT OBU and ITS in one equipment device.

Possible interference mitigation factors and channel access mechanisms will be investigated by ERM TG37 in the course of the sharing studies to be performed within CEPT ECC WGSE provided that results will indicate the need for such measures.

History

Document history		
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