ETSI TR 103 721 V1.1.1 (2023-05)

Feasibility assessment of applying mitigation techniques to WAS/RLAN to enable coexistence in the 5 725 MHz to 5 850 MHz band

Reference

DTR/BRAN-230023

Keywords

radar, RLAN, WAS

ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00   Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - APE 7112B
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° w061004871

Contents

Intellectual Property Rights

Essential patents

IPRs essential or potentially essential to normative deliverables may have been declared to ETSI. The declarations pertaining to these essential IPRs, if any, are publicly available for **ETSI members and non-members**, and can be found in ETSI SR 000 314: *"Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards"*, which is available from the ETSI Secretariat. Latest updates are available on the ETSI Web server (https://ipr.etsi.org/).

Pursuant to the ETSI Directives including the ETSI IPR Policy, no investigation regarding the essentiality of IPRs, including IPR searches, has been carried out by ETSI. No guarantee can be given as to the existence of other IPRs not referenced in ETSI SR 000 314 (or the updates on the ETSI Web server) which are, or may be, or may become, essential to the present document.

Trademarks

The present document may include trademarks and/or tradenames which are asserted and/or registered by their owners. ETSI claims no ownership of these except for any which are indicated as being the property of ETSI, and conveys no right to use or reproduce any trademark and/or tradename. Mention of those trademarks in the present document does not constitute an endorsement by ETSI of products, services or organizations associated with those trademarks.

DECT™, **PLUGTESTS™**, **UMTS™** and the ETSI logo are trademarks of ETSI registered for the benefit of its Members. **3GPP™** and **LTE™** are trademarks of ETSI registered for the benefit of its Members and of the 3GPP Organizational Partners. **oneM2M™** logo is a trademark of ETSI registered for the benefit of its Members and of the oneM2M Partners. **GSM**® and the GSM logo are trademarks registered and owned by the GSM Association.

Copyright acknowledgment ©

OpenStreetMap contributors - www.openstreetmap.org/copyright.

Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Broadband Radio Access Networks (BRAN).

Modal verbs terminology

In the present document "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

"**must**" and "**must not**" are **NOT** allowed in ETSI deliverables except when used in direct citation.

Introduction

The present document studies the feasibility and impact on WAS/RLAN operation with regards to proposals for additional mitigation techniques to those currently implemented in WAS/RLANs to enable sharing with Road Tolling and Transport equipment within the 5 795 MHz to 5 815 MHz and some modes of fast frequency hopping radar not covered by DFS that operate in the 5 725 MHz to 5 850 MHz frequency range within some CEPT countries. The present document is a next step in a series of studies and regulatory developments regarding sharing conditions and mitigation techniques applicable in the 5 725 MHz to 5 850 MHz band. Its goals and meaning may become clearer with the help of a review of recent history of sharing studies.

History of Sharing studies with Road Tolling

As part of the previous studies in ECC Report 244 [i.7], MCL calculations for possible interference from RLANs into fixed road tolling have been performed and showed the need for separation distances if compatibility is dependent upon protection to an I/N level of -6 dB.

ECC Report 244 [i.7] suggested the following approaches:

- Implementation in RLAN of a detection mechanism to detect road tolling applications based on energy detection. Under the assumptions considered, preliminary analysis indicated that for an RLAN system operating with 23 dBm/20 MHz a detection threshold of the order of -100 dBm/500 kHz and for a RLAN system with 23 dBm/160 MHz a detection threshold of the order of -90 dBm/500 kHz would be required for a reliable detection of road tolling. Further consideration is required, including on the feasibility of such a detection threshold and its impact on the RLAN operation.

- Transmission from the road tolling applications of predefined signals (beacons) which indicate that the used channels are busy, similar to one of the mitigation techniques used to facilitate ITS and Road Tolling adjacent channel coexistence.

- Ensure coexistence with the road tolling systems through the detection of ITS. This is based on the assumption that there will always be ITS systems in the close vicinity of road-tolling road-side units. Under this approach, once ITS have been detected by RLAN under the conditions described in clause 2 of ECC Report 244 [i.7], the road tolling frequency band 5 795 MHz to 5 815 MHz will also be considered as occupied and thus, not available for RLAN use.

- Use of geo-location database approach. The geo-location database should hold actual information from static and, due to construction sites, temporary tolling installations. The implementation of such a platform, its access and its maintenance should be addressed. In addition, the role and responsibilities of the stakeholders have to be clearly defined.

In connection with that, work on mitigation techniques was initiated in ETSI TC BRAN, which resulted in ETSI TR 103 319 [i.21]. ETSI TR 103 319 [i.21] structured the aforementioned approaches into detection and mitigation parts and provided an evaluation of each detection method and mitigation technique. Further related work on WAS/RLAN technology operating under SRD regulation in vehicles has been performed in ECC Report 277 [i.32], where it was indicated that the tolling signal triggers the IEEE 802.11™ [i.2] energy detection, but the detection range was smaller than the interference range at 25 mW.

Further work was carried out in ETSI standards to look at sharing between road-tolling technologies and other specific applications which already use RLAN technologies. Some of the specific mitigation techniques contained in ETSI TR 103 319 [i.21] have been implemented in some other Harmonised Standards to enable sharing between road-tolling and other specific applications which already use RLAN technologies: notably Wireless Industrial Technologies (ETSI EN 303 258 [i.33]) and ITS (ETSI EN 302 571 [i.34], also see ETSI TS 102 792 [i.22]), which include the use of a geo-location database of road tolling installations.

ECC Report 330 [i.18] studied WAS/RLAN use on a national basis in the band 5 725 MHz to 5 850 MHz while ensuring the protection of RTTT/Smart Tachograph and radars (including Fast Frequency Hopping) and taking into account free circulation of WAS/RLAN. While it does not contain new compatibility studies, ECC Report 330 [i.18] introduced a new mitigation approach based on a Country Determination Capability (CDC), which is a "functionality implemented on the device which aims to decide if the device is allowed or not to use the spectrum depending on the current country location of the device and its regulatory framework". Further to that, ECC Report 330 [i.18] recommended "that the use of the band by fixed outdoor installations or installations in vehicles is not allowed for devices operating above 25 mW EIRP".

History of Sharing studies with Radar

In the bands 5 250 MHz to 5 350 MHz and 5 470 MHz to 5 725 MHz, DFS was made mandatory for WAS/RLAN devices operating in master (primary device) mode, or operating above 200 mW EIRP. This enabled uncoordinated licence exempt use of WAS/RLANs in these bands up to 1W EIRP indoor and outdoor. Dynamic Frequency Selection (DFS) is a mitigation technique that allows WAS/RLANs to automatically avoid co-channel operation with some operational modes of certain radars.

DFS requirement was made part of the requirements included in harmonised standards ETSI EN 301 893 [i.4] and ETSI EN 302 502 [i.29]. Nevertheless, when reviewing coexistence options between WAS/RLAN and radar systems in the 5 725 MHz to 5 850 MHz band, neither CEPT Report 57 [i.5] nor CEPT Report 64 [i.6] found conclusive evidence that sharing can be achieved. In the time frame of developing the aforementioned reports, doubts were raised whether DFS was able to protect radar modes of operation which had not been included in the original version of Recommendation ITU-R M.1638, but were to appear in Recommendation ITU-R M.1638-1 [i.19]. Both CEPT Report 57 [i.5] and CEPT Report 64 [i.6] noted that further mitigation techniques were needed to enable sharing between WAS/RLAN and radars operating in the 5 725 MHz to 5 850 MHz band.

Both reports also noted that the 5 725 MHz to 5 850 MHz band is an ISM band and that there already were applications operating, such as BFWA and SRD, with and without DFS, at various power levels, and under different ECC deliverables. The reports suggested that when discussing appropriate mitigation techniques for RLANs, the impact of interference from these existing applications into radiolocation systems would need to be considered for comparison purposes.

During European preparations for WRC-19, technical assessments were performed (see ITU-R WP5A Contribution 1031 (2015-2019)) [i.20] to evaluate the performance of DFS metrics based on Recommendation ITU-R M.1652-1 [i.3] when applied to representative signals for Fast Frequency Hopping radar numbers 22 and 23 from the updated Recommendation ITU-R 1638-1 [i.19]. It should be noted that FFH radars operating in 5 725 MHz to 5 850 MHz band are dedicated to military applications. Theoretical analysis contained in the contribution indicated that current DFS mitigation techniques cannot detect the operating modes/signals of FFH radars studied before disruption can occur to these radar operations. Similarly, to CEPT Report 57 [i.5] and CEPT Report 64 [i.6], this contribution concluded that without additional mitigation techniques, sharing between WAS/RLAN and FFH radars operating in the 5 725 MHz to 5 850 MHz band would not be possible.

As a result, the CEPT position for Agenda Item 1.16 (WRC-19) for 5 725 MHz to 5 850 MHz band was "No Change (NOC)" with respect to the proposal for a primary mobile allocation in the band. Nevertheless, some CEPT countries indicated that they would like to open the band for WAS/RLAN use. Therefore, CEPT agreed to initiate a work item to provide guidance on possible mitigation techniques for the possible use of WAS/RLAN in the 5 725 MHz to 5 850 MHz band in these CEPT countries. The result was ECC Report 330 [i.18].

While not containing any new compatibility studies, nor any harmonization measures, ECC Report 330 [i.18] introduced several new considerations on coexistence of WAS/RLAN with radars, including fast frequency hopping radars. Provided that WAS/RLAN equipment put on the European market may freely circulate at the EU level, the present document recommends that an automated Country Determination Capability (CDC) functionality be developed in ETSI and made a requirement for WAS/RLAN Access Points capable of transmitting over 25 mW EIRP. With this capability, the device would automatically check whether it is allowed or not to use the 5 725 MHz to 5 850 MHz band depending on the country the device is currently located in.

The present document also concludes that countries implementing WAS/RLAN using higher powers than 25 mW EIRP will have to consider how to address any possible cross border interference issues. This includes even those countries that do not have FFH radars operating in this band, because available DFS techniques will not automatically protect FFH radars operating abroad. Finally, the present document recommends to countries wishing to open the 5 725 MHz to 5 850 MHz band to WAS/RLAN devices that use by fixed outdoor installations or installations in vehicles is not allowed for devices operating above 25 mW EIRP.

1 Scope

The present document contains a review of the feasibility of implementing certain mitigation techniques in WAS/RLAN equipment in the 5 725 MHz to 5 850 MHz frequency range. The present document has been triggered by the Work Item agreed in CEPT to study the possible use of WAS/RLANs in some CEPT countries as a result of the work and discussions on the EC Mandate on 5 GHz [i.1] and WRC-19 Agenda Item 1.16.

The present document is intended to study the feasibility of implementing additional mitigation techniques in WAS/RLANs to provide possible sharing solutions between WAS/RLAN and the following services and applications operating in some CEPT countries:

- Road tolling in the bands 5 795 MHz to 5 815 MHz.
- Smart-Tachograph, (weights and dimensions); band (5 795 MHz to 5 815 MHz).
- Some modes of fast frequency hopping radar not specifically covered in WAS/RLAN DFS algorithms today; band 5 725 MHz to 5 850 MHz.

WAS/RLAN technologies meeting the scope and requirements contained within ETSI EN 301 893 [i.4] and ETSI EN 302 502 [i.29] as well as any additional mitigation techniques studies as part of the present document are considered in the present document. See clause 4 for more detailed information on the services and applications being studied in the present document.

WAS/RLAN technologies with an output power of less than or equal to 25 mW EIRP can operate within the scope of ERC/REC 70-03 [i.11] annex 1, and as such are outside the scope of the present document.

2 References

2.1 Normative references

Normative references are not applicable in the present document.

2.2 Informative references

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

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

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

[i.1] Mandate to CEPT to study and identify harmonised compatibility and sharing conditions for Wireless Access Systems including Radio Local Area Networks in the bands 5350-5470 MHz and 5725-5925 MHz ('WAS/RLAN extension bands') for the provision of wireless broadband services.

[i.2] IEEE Std. 802.11™-2016: "IEEE Standard for Information technology--Telecommunications and information exchange between systems Local and metropolitan area networks--Specific requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications".

[i.3] Recommendation ITU-R M.1652-1: "on Dynamic frequency selection in wireless access systems including radio local area networks for the purpose of protecting the radio-determination service in the 5 GHz band".

[i.4] ETSI EN 301 893 (V2.1.1): "5 GHz RLAN; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU".

[i.5] CEPT Report 57: "Compatibility and sharing conditions for WAS/RLAN in the bands 5350-5470 MHz and 5725-5925 MHz". .

[i.6] CEPT Report 64: "To study and identify harmonised compatibility and sharing conditions for Wireless Access Systems including Radio Local Area Networks in the bands 5350-5470 MHz and 5725-5925 MHz ('WAS/RLAN extension bands') for the provision of wireless broadband services".

[i.7] ECC Report 244: "Compatibility studies related to RLANs in 5725-5925 MHz".

[i.8] ECC/DEC/(02)01: "ECC Decision of 15 March 2002 on the frequency bands to be designated for the co-ordinated introduction of Road Transport and Traffic Telematic Systems".

[i.9] ECC/DEC(12)04 : "ECC Decision on 02 November 2012 on the withdrawal of ECC Decision (02)01".

[i.10] Directive 2004/52/EC of the European Parliament and of the Council of 29 April 2004 on the interoperability of electronic road toll systems in the Community.

[i.11] ERC Recommendation 70-03: "Relating to the use of Short Range Devices (SRD)".

[i.12] ETSI EN 300 674-2-1 (V2.1.1): "Transport and Traffic Telematics (TTT); Dedicated Short Range Communication (DSRC) transmission equipment (500 kbit/s / 250 kbit/s) operating in the 5 795 MHz to 5 815 MHz frequency band; Part 2: Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU; Sub-part 1: Road Side Units (RSU)".

[i.13] ETSI EN 300 674-2-2 (V2.1.1): "Transport and Traffic Telematics (TTT); Dedicated Short Range Communication (DSRC) transmission equipment (500 kbit/s / 250 kbit/s) operating in the 5 795 MHz to 5 815 MHz frequency band; Part 2: Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU; Sub-part 2: On-Board Units (OBU)".

[i.14] Commission Implementing Regulation (EU) 2016/799 of 18 March 2016 implementing Regulation (EU) No 165/2014 of the European Parliament and of the Council laying down the requirements for the construction, testing, installation, operation and repair of tachographs and their components.

[i.15] Directive (EU) 2015/719 of the European Parliament and of the Council of 29 April 2015 amending Council Directive 96/53/EC laying down for certain road vehicles circulating within the Community the maximum authorised dimensions in national and international traffic and the maximum authorised weights in international traffic.

[i.16] ETSI ES 200 674-1 (V2.4.1): "Intelligent Transport Systems (ITS); Road Transport and Traffic Telematics (RTTT); Dedicated Short Range Communications (DSRC); Part 1: Technical characteristics and test methods for High Data Rate (HDR) data transmission equipment operating in the 5,8 GHz Industrial, Scientific and Medical (ISM) band".

[i.17] ETSI TR 102 960 (V1.1.1): "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.18] ECC Report 330: "To enable WAS/RLAN use on a national basis in the band 5725-5850 MHz but also ensure the protection of RTTT/Smart Tachograph and radars (including Fast Frequency Hopping) taking into account free circulation of WAS/RLAN".

[i.19] Recommendation ITU-R M.1638-1: "Characteristics of and the protection criteria for sharing studies for radiolocation (except ground based meteorological radars) and aeronautical radionavigation radars operating in the frequency bands between 5250-5850 MHz".

[i.20] ITU-R WP5A Contribution 1031 (2015-2019): "Statistical study between WAS/RLAN and frequency hopping radars in the 5725-5850 MHz frequency band".

[i.21] ETSI TR 103 319 (V1.1.1): "Broadband Radio Access Networks (BRAN); 5 GHz high performance RLAN; Mitigation techniques to enable sharing between RLANs and Road Tolling and Intelligent Transport Systems in the 5 725 MHz to 5 925 MHz band".

[i.22] ETSI TS 102 792 (V1.2.1): "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.23] EN 12253:2004: "Road transport and traffic telematics - Dedicated short-range communication - Physical layer using microwave at 5,8 GHz", (produced by CEN).

[i.24] EN 12795:2003: "Road transport and traffic telematics - Dedicated Short Range Communication (DSRC) - DSRC data link layer: medium access and logical link control", (produced by CEN).

[i.25] EN 12834:2003: "Road transport and traffic telematics - Dedicated short-range communication - (DSRC) DSRC Application Layer", (produced by CEN).

[i.26] EN 13372:2004: "Road transport and traffic telematics (RTTT) - Dedicated short-range communication - Profiles for RTTT Applications", (produced by CEN).

[i.27] Commission Implementing Decision (EU) 2022/180 of 8 February 2022 amending Decision 2006/771/EC as regards the update of harmonised technical conditions in the area of radio spectrum use for short-range devices. .

[i.28] ECO Report 06: "Country Determination Capability, National use of the 5725-5850 MHz frequency band by WAS/RLAN devices with maximum power higher than 25 mW and up to 200 mW e.i.r.p. in CEPT countries".

[i.29] ETSI EN 302 502 (V2.1.3): "Wireless Access Systems (WAS); 5,8 GHz fixed broadband data transmitting systems; Harmonised Standard for access to radio spectrum".

[i.30] ETSI EN 302 637-2 (V1.4.1): "Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service".

[i.31] ETSI TS 102 894-2 (V1.3.1): "Intelligent Transport Systems (ITS); Users and applications requirements; Part 2: Applications and facilities layer common data dictionary".

[i.32] ECC Report 277: "Use of SRD applications in cars in the band 5725-5875 MHz".

[i.33] ETSI EN 303 258 (V1.1.1): "Wireless Industrial Applications (WIA); Equipment operating in the 5 725 MHz to 5 875 MHz frequency range with power levels ranging up to 400 mW; Harmonised Standard for access to radio spectrum".

[i.34] ETSI EN 302 571 (V2.1.1): "Intelligent Transport Systems (ITS); Radiocommunications equipment operating in the 5 855 MHz to 5 925 MHz frequency band; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU".

[i.35] Directive (EU) 2019/520 of the European Parliament and of the Council of 19 March 2019 on the interoperability of electronic road toll systems and facilitating cross-border exchange of information on the failure to pay road fees in the Union.

[i.36] European Agreement concerning the Works of Crews of Vehicles Engaged in International Road Transport (AETR), Geneva, 1 July 1970.

[i.37] ECC Report 101: "Compatibility studies in the band 5855- 5925 MHz between Intelligent Transport Systems (ITS) and other systems".

[i.38] ECC Report 228: "Compatibility studies between Intelligent Transport Systems (ITS) in the band 5855-5925 MHz and other systems in adjacent bands".

[i.39] 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.40] ECC/DEC(02)02: "ECC Decision of 15 March 2002 on the withdrawal of the ERC Decision (92)02 Decision on the frequency bands to be designated for the co-ordinated introduction of Road Transport Telematic Systems".

[i.41] ECC Report 250: "Compatibility studies between TTT/DSRC in the band 5805-5815 MHz and other systems".

3 Definition of terms, symbols and abbreviations

3.1 Terms

Void.

3.2 Symbols

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

t1 to t10	short training symbols
T1, T2	long training symbols
GI, GI2	Guard intervals

3.3 Abbreviations

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

BFWA	Broadband Fixed Wireless Access
CAM	Cooperative Awareness Message
CDC	Country Determination Capability
CEN DSRC	Dedicated Short Range Communications

NOTE: As defined by The European Committee for Standardization.

DFS	Dynamic Frequency Selection
DSRC	Dedicated Short Range Communication
EFC	Electronic Fee Collection
EIRP	Equivalent Isotropic Radiated Power
FFH	Fast Frequency Hopping
GNSS	Global Navigation Satellite System
HDR	High Data Rate
I/N	Interference-to-Noise ratio
IEEE	Institute of Electrical and Electronics Engineers
ISM	Industrial, Scientific and Medical
ITS	Intelligent Traffic Systems
ITS-G5	Intelligent Transport Systems operating in the 5 GHz band
MAC	Medium Access Control
MCL	Minimum Coupling Loss
MLFF	Multi-Lane Free Flow
OBU	On-Board Unit
PHY	Physical layer
RF	Radio Frequency
RLAN	Radio Local Area Network
RSU	Road Side Unit
SINR	Signal to Interference plus Noise Ratio
SRD	Short Range Device
TPC	Transmitter Power control
TTT	Transport and Traffic Telematics
WAS	Wireless Access Systems

4 Overview of services under study

4.1 Existing/Proposed WAS/RLAN

4.1.1 Overview

Transport and Traffic Telematic (TTT) are 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. vehicle-to-vehicle), and between vehicles and fixed locations (e.g. vehicle-to-infrastructure). In the actual regulatory discussion and documents RTTT is being replaced with TTT, see ERC/REC 70-03 [i.11].

This clause details proposed WAS/RLAN parameters and technical characteristics for the 5 725 MHz to 5 850 MHz band applicable in some CEPT member states. It should be noted that there is no harmonisation measure within CEPT for WAS/RLAN operating above 25 mW EIRP in the 5 725 MHz to 5 850 MHz band, whilst operation up to 25 mW EIRP is covered by ERC/REC 70-03 [i.11], annex 1.

4.1.2 Technical characteristics of WAS/RLAN operating in the 5 725 MHz to 5 850 MHz band

The technical characteristics of WAS/RLAN systems operating in the 5 725 MHz to 5 850 MHz band can be seen in Section 2.3 of ECC Report 244 [i.7].

WAS/RLAN requirements for the 5 725 MHz to 5 850 MHz band are defined in annex B of ETSI EN 301 893 [i.4].

4.2 Transport and Traffic Telematics (TTT)

4.2.1 Overview

This clause details existing TTT regulations and technical characteristics for the 5 795 MHz to 5 815 MHz band. This band is identified in annex 5 of ERC/REC 70-03 [i.11] (TTT frequency band a and b), and in Commission Implementing Decision (EU) 2022/180 [i.27] for road tolling applications and smart tachograph, weight and dimension applications.

4.2.2 Road-tolling applications in the band 5 795 MHz to 5 815 MHz

Electronic road toll systems are typically used for the automatic collection of fees for road usage. In Europe, there are mainly two types of systems for tolling which are subject to tolling interoperability regulation in Directive (EU) 2019/520 [i.35]:

- Dedicated Short-Range Communications (DSRC) which is a short range microwave technology that is operated in the TTT band 5 795 to 5 815 MHz and based on CEN DSRC standards in Europe [i.23], [i.24], [i.25] and [i.26] with the exception of Italy, where a variant High Data Rate (HDR) DSRC is used.

- Satellite/GNSS-based systems, usually used in combination with DSRC.

DSRC is used for the tolling and tolling enforcement, which requires the ability to automatically check whether a tolling On-Board Unit (OBU) is correctly installed and working in a vehicle. DSRC is also used for enforcement in Satellite/GNSS-based systems, where fees depend on the recorded GNSS trajectory, but the vehicle's OBU status is checked via DSRC communication (see ECC Report 250, [i.41] annex 2 on the German Tolling System).

DSRC at 5,8 GHz is used in over 20 countries in Europe. According to the statistics from members of ASECAP, the European Association of Operators of toll road infrastructures, 29 million TTT OBUs are in use. The revenue for all kinds of tolling is 29 billion Euros and the TTT based tolling is a substantial part of this. Revenues from TTT road toll systems are an important income to build and maintain road infrastructure in Europe [i.5].

In DSRC based tolling systems, vehicles are equipped with on-board units (also called "tags") that communicate with Road Side Units (RSUs) installed on toll roads. Road side units (also called "beacons" or "reader") initiate the communication. RSUs can be found in the following configurations:

- Toll plaza with barrier: the RSU is mounted next to / over a lane, the barrier is opened upon successful completion of the tolling transaction.
- Toll plaza with Electronic Fee Collection (EFC) lane: the RSU is mounted over a lane, where the vehicle passes at low speed; EFC lanes are also used by ferry operators.
- Free flow tolling: RSUs are mounted on overhead gantries, one RSU per lane.
- Fixed and mobile enforcement: RSUs are mounted on overhead gantries, road-side poles or on enforcement vehicles.

On-board units operate in passive backscatter mode, a design without active transmitter which allows low unit cost, low power consumption and long battery lifetime. A specific characteristic of the system is that the roadside equipment has a high sensitivity in order to be able to decode the reflected signal of the OBU. The high sensitivity of the Road Side Unit (RSU) makes it more vulnerable for in-band interference. An OBU is waked up by the signal of the RSU followed by an exchange of several frames, which together form a tolling transaction. Single frames within the tolling transaction can be repeated. However, in free flow tolling, there is limited time to complete the transactions, because a vehicle spends limited time within the communication zone. In single-lane systems with barrier, repeated interference could block the barrier from opening.

Regulation in CEPT on road tolling goes back to ECC/DEC(02)02 [i.40]on the co-ordinated introduction of Road Transport Telematic Systems. This decision identified the frequencies for road tolling applications in the band 5 795 MHz to 5 815 MHz. It has been replaced by ECC/DEC/(02)01 [i.8], where the term Road Transport and Traffic Telematic (RTTT) Systems was used, and later repealed by ECC/DEC(12)04 [i.9] because of availability of applicable EU legislation (Directive 2004/52/EC [i.10]). Subsequently, RTTT was included in the EC Decision on SRDs (2006/771/EC [i.43]) within its 5th update. The name was later simplified to "Transport and Traffic Telematics" (TTT).

Many European countries have practical implementations of road tolling equipment either as nationwide road tolling equipment or local road tolling equipment (major bridges, individual toll roads or city toll system). The majority of such installations comply with ETSI EN 300 674-2-1 [i.12] and ETSI EN 300 674-2-2 [i.13] and use all four 5 MHz wide channels up to 2 W EIRP per channel for the road side units. The use of 8 W roadside unit equipment is not common and may require individual license.

There are also more than 1 000 small systems implemented throughout Europe over the last 15 to 20 years which are operated in individual buildings, pre-dominantly in parking garages, which are not strictly speaking "road tolling" systems. These applications operate under a more relaxed national regulatory regime.

4.2.3 Smart tachograph applications

The smart tachograph introduction and the enforcement of weight and dimension both impact traffic safety and fair competition on the road transport market. Additionally, the digital tachograph is used to guarantee correct working conditions for truck drivers as prerequisite for safe driving. The EU regulated the radio technology to be used for the remote enforcement (i.e. wireless interrogation) of the tachograph in Appendix 14 of the Commission Implementing Regulation 2016/799 [i.14] and for the weight and dimension enforcement in Article 10d of the Directive 2015/719 [i.15]. This radio technology is CEN DSRC at 5,8 GHz, similar to road tolling equipment and uses the same harmonised standards. EU countries and some non-EU countries (EEA countries, CH, UK) have implemented the Smart Tachograph. The control of driving times and rest periods is also subject to the European Agreement Concerning the Work of Crews of Vehicles (AETR) [i.36]. The agreement has 49 contracting parties including all EU Member States. It was amended in 2006 in order to introduce the digital tachograph.

4.2.4 Technical characteristics

The technical characteristics of the road tolling systems used in the present document can be seen in annex 2 of ECC Report 244 [i.7].

The regulatory parameters (maximum power levels) for road-tolling systems are given in annex 5 of ERC/REC 70-03 [i.11].

Road tolling requirements are defined in the ETSI standards ETSI EN 300 674-2-1 [i.12] for On-Board Units (OBU) and ETSI EN 300 674-2-2 [i.13] for Road Side Units (RSUs). In Italy a special version of Road Tolling TTT is used, defined in ETSI ES 200 674-1 [i.16]. Interference effects of 5 GHz WAS/RLAN on this type of TTT system have not been specifically considered in the analysis of the present document.

4.3 Radiodetermination services in the 5 725 MHz to 5 850 MHz band

4.3.1 Overview

This clause details technical characteristics of existing radiodetermination services for the 5 250 MHz to 5 850 MHz band.

Fast Frequency Hopping (FFH) is one of the most common Electronic-Counter-Counter-Measures (ECCM) Radar systems that are designed to operate in hostile electronic attack environments use frequency hopping as one of its ECCM techniques. This type of radar typically divides its allocated frequency band into channels. The radar then randomly selects a channel from all available channels for transmission. This random occupation of a channel can occur on a per beam position basis where many pulses on the same channel are transmitted or on a per pulse basis.

4.3.2 Radar Operations in the 5 250 MHz to 5 850 MHz bands

In some CEPT countries where FFH radars modes operate in the band 5 725 MHz to 5 850 MHz their radar operations cannot be detected by the DFS requirements in current ETSI Harmonised Standards.

While the present document focuses on some modes of fast frequency hopping radar in the 5 725 MHz to 5 850 MHz band not specifically covered in RLAN DFS algorithms today, there are certain broader aspects of radar deployment that are relevant for evaluating possible interference scenarios.

Not all types of Radar operate across the whole 5 250 MHz to 5 850 MHz band, allocated to radiolocation service in ITU Region 1. Some defence radars, including fast frequency hopping radars, are able to operate throughout the whole frequency range or most of it, while other radars are only able to use a part of the whole frequency range. In the case of frequency hopping radars, frequency agility and adaptive hopping technologies have been specifically developed as a mitigation technique against intentional jamming and to avoid detection. The larger the frequency range a frequency hopping radar is using, the more efficiently it can avoid potential interference. Conversely, the smaller the frequency range that can be used, the more likely the interference is going to be harmful for the radar.

As argued elsewhere in the present document, current DFS requirements contained in both ETSI EN 301 893 [i.4] and ETSI EN 302 502 [i.29] as well as the parameters contained in Recommendation ITU-R M.1652-1 [i.3] for DFS are not sufficient to protect all of the FFH radar operating modes. That implies that potential sources of interference will exist in the 5 470 MHz to 5 725 MHz band, where WAS/RLANs are authorized to operate under harmonized conditions. WAS/RLANs are not authorized to operate in the 5 350 MHz to 5 470 MHz band under harmonized conditions, and this band can be used by fast frequency hopping radars to avoid interference. However, the operating range of some frequency hopping radar is limited to 5 400 MHz to 5 850 MHz. The 5 400 MHz to 5 470 MHz frequency range alone will not be large enough for some current fast frequency hopping radars to avoid interference. These radars may suffer from harmful interference, unless additional mitigation techniques are introduced in the 5 725 MHz to 5 850 MHz band.

It should be noted that some radars can both, use all of the WAS/RLAN-free spectrum available in the 5 350 MHz to 5 470 MHz band and frequency hopping modes that are recognized by current DFS mechanisms, which aids their protection from interference.

4.3.3 Technical characteristics

The technical characteristics of the Fast Frequency Hopping Radar systems that are under the scope of the present document are provided by Recommendation ITU-R M.1638-1 [i.19] Characteristics of and the protection criteria for sharing studies for radiolocation (except ground based meteorological radars) and aeronautical radionavigation radars operating in the frequency bands between 5 250 MHz to 5 850 MHz. These technical characteristics are shown in Table 1.

Table 1: Additional technical characteristics of ground based radars in the radiolocation service operating in frequency bands 5 725 MHz to 5 850 MHz

Characteristics		Unit	Radar 22	Radar 23
Function			Multi-function	Multi-function
Platform type (airborne, shipborne, ground)			Surface and air search, ground-based on vehicle	Search, ground-based on vehicle
Tuning range		MHz	5 400 to 5 850	5 250 to 5 850
Modulation			Coded pulse/barker code and Frequency hopping	Coded pulse/barker code and Frequency hopping
Tx power into antenna		kW	12 peak	70
Pulse width		µS	4,0 to 20,0	3,5/6,0/1,0
Pulse rise/fall time		µS	0,2	0,3
Pulse repetition rate		Pps	1 000 to 7 800	2 500 to 3 750
Chirp bandwidth		MHz	NA	NA
RF emission bandwidth	-3 dB -20 dB	MHz	5 Not available	5 Not available
Antenna pattern type (pencil, fan, cosecant-squared, etc.)			Pencil	Pencil
Antenna type (reflector, phased array, slotted array, etc.)			Phased array	Phased array
Antenna polarization			Vertical	Horizontal
Antenna main beam gain		dBi	35	31,5
Antenna elevation beamwidth		Degrees	30	30
Antenna azimuthal beamwidth		Degrees	2	2
Antenna horizontal scan rate		Degrees/s	Variable	Variable
Antenna horizontal scan type (continuous, random, 360°, sector, etc.)		Degrees	360	360 sector
Antenna vertical scan rate		Degrees	Not applicable	Not applicable
Antenna vertical scan type (continuous, random, 360°, sector, etc.)		Degrees	Sector	Sector
Antenna Side-Lobe (SL) levels (1st SLs and remote SLs)		dB	-40	-30
Antenna height		m	10	6 to 13
Receiver IF 3 dB bandwidth		MHz	4	5
Receiver noise figure		dB	5	13
Minimum discernible signal		dBm	-103	-108

5 Interference scenarios

5.1 Introduction

5.1.1 Overview

This clause sets out the most common interference scenarios between WAS/RLAN and the various TTT and Radar services in the and 5 725 MHz to 5 850 MHz frequency range. It should be noted that there is also potential for interference into TTT and ITS in the 5 855 MHz to 5 925 MHz frequency range, further discussed in annex A.

5.1.2 WAS/RLAN and Road Tolling/Smart-Tachograph - description of scenarios

The following scenarios describe realistic, worst-case scenarios applicable to both directions of interference between WAS/RLAN and road tolling.

The scenarios described here have been studied in ECC Report 244 [i.7], where MCL calculations showed the need for significant separation distances. For vehicles, ECC Report 330 [i.18] recommended "that the use of the band by fixed outdoor installations or installations in vehicles is not allowed for devices operating above 25 mW EIRP".
Indoor and outdoor WAS/RLANs can be distinguished by its operation:

- Enterprise WAS/RLAN, centrally managed
- WAS/RLAN managed by the Internet Service Provider
- WAS/RLAN installed and managed by end user

Scenario A1: Indoor WAS/RLAN

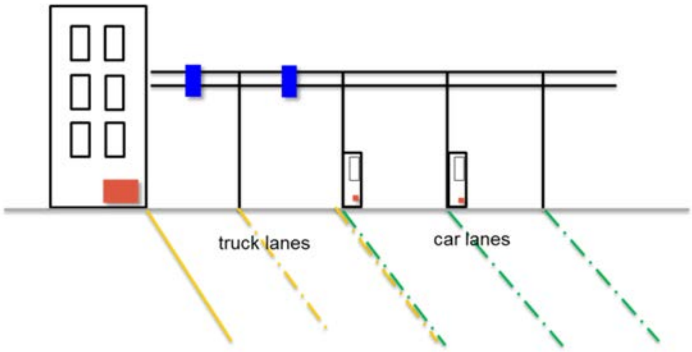

Figure 1: Scenario A1 - road tolling

The 5 GHz WAS/RLAN device is situated close to the road tolling system. Figure 1 above shows an example with multilane road toll stations. The 5 GHz WAS/RLAN transmitter appears in red and the tolling road-side units are shown in blue. In this scenario it is assumed that the 5 GHz WAS/RLAN device is close to the road tolling communication zone, but situated inside a building. Under this scenario, the minimum distance between the 5 GHz WAS/RLAN transmitter and the tolling roadside receiver antenna can be around a few meters.

There are also other possible scenarios, the multilane road toll stations depicted here is just an example. Other examples could be tolling points within city centres, access to parking lots, etc. Buildings close to the streets not being owned or controlled by the tolling operator are considered, where WAS/RLAN devices could be operated without any consent of the tolling operator.

Scenario A2: outdoor WAS/RLAN
This is the same as scenario A1 except that the WAS/RLAN device is situated outside of a building.

Scenario A3: RLAN on-board a vehicle

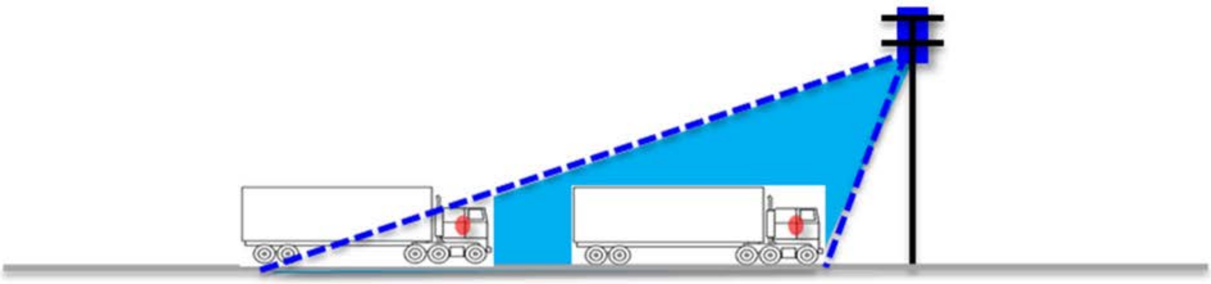

Figure 2: Scenario A3 - road tolling

Here the 5 GHz RLAN transmitters are found inside the vehicle as studied in ECC report 244 [i.7].

Current regulation within CEPT do not permit the use of WAS/RLAN operating above 25 mW EIRP inside a vehicle in the 5 725 MHz to 5 850 MHz band.

Scenario A4: Smart Tachograph

Smart tachograph enforcement is performed by a Remote Early Detection Communication Reader (REDCR) from the roadside or from within a vehicle. In the roadside interrogation use case of (EU) 2016/799 [i.14] the reader is positioned close to a road (e.g. on a tripod) for a temporary period before changing location. In the vehicle based interrogation, the mobile reader is carried by an enforcement vehicle. Fixed enforcement installations are also possible in the future; they will be similar to free-flow road tolling installations.

In this scenario, WAS/RLAN could be installed indoor in a nearby building or outdoor, as in Scenarios A1 and A2 above.

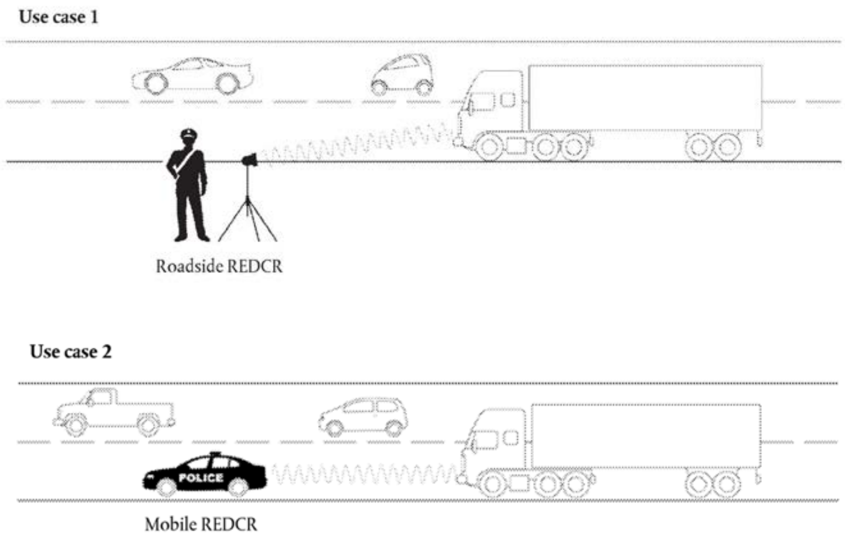

Figure 2A: Scenario A4 - Smart tachograph use cases

5.1.3 WAS/RLAN and Radar Operations - description of scenarios

Scenario B1: Outdoor WAS/RLAN

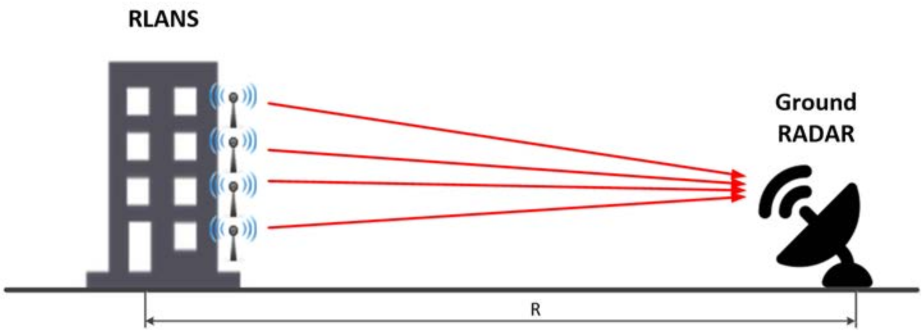

Figure 3: Scenario B1 - ground radar

In this scenario, WAS/RLAN devices positioned outdoor are interfering with ground radar receiver. For instance, these WAS/RLAN devices could be access points or clients for fixed broadband access, installed on residence buildings. ECC Report 330 [i.18] in section A1.1.2 contains considerations, from the Czech Republic national approach, comparing interference from currently deployed devices, such as SRD's (up to 25 mW EIRP) operating in the 5 725 MHz to 5 850 MHz band, with interference that could be received from WAS/RLAN devices; this also includes considerations on aggregate effects of multiple WAS/RLAN devices in rural and urban areas. An important aspect of the scenario is whether the radar location is known or may be assumed, including cases when the location is restricted to a certain area, such as military training ground. In these cases, protection zones are easier to establish, as per the example in figure 4 below.

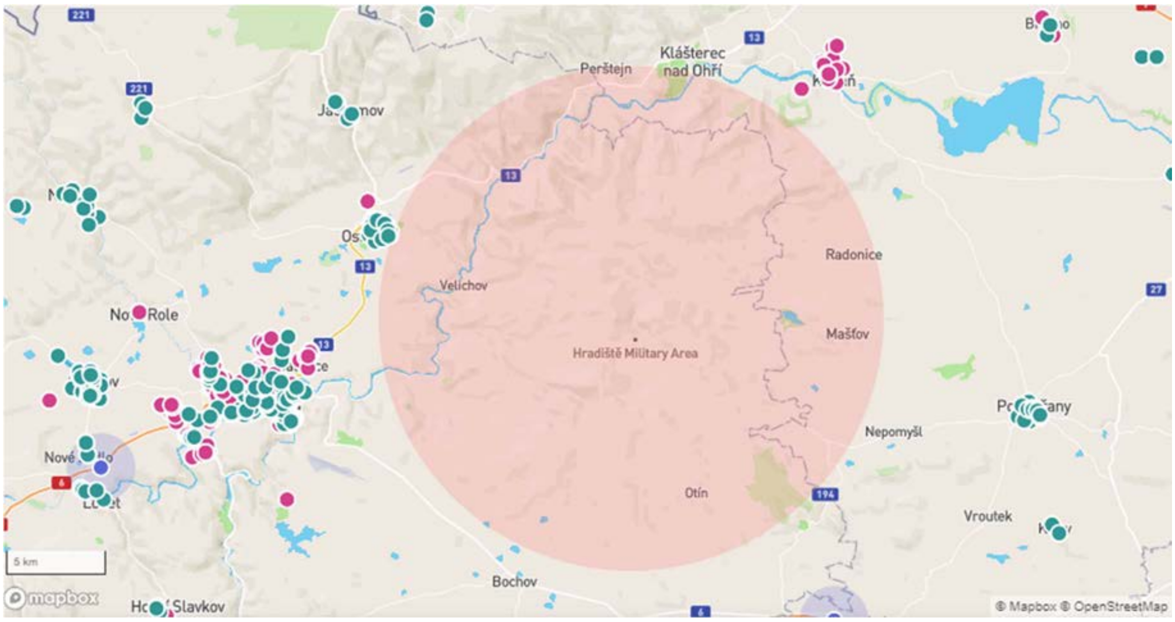

Figure 4: Protection zone around a military area with an assumed defence ground radar position, based on a 13 km separation distance (ECC Report 330 [i.18])

Scenario B2: Indoor WAS/RLAN

This is the same as scenario B1 except that the WAS/RLAN devices are situated inside of a building, and therefore building entry loss applies.

6 Measures to enable coexistence

6.1 Introduction

The following clauses explore various techniques that are available to allow the coexistence of WAS/RLAN with the applications of TTT and Radar in the 5 725 MHz to 5 850 MHz band.

Recent CEPT documents such as ECC Report 330 [i.18], CEPT Report 64 [i.6], CEPT Report 57 [i.5] or ECC Report 244 [i.7] would typically discuss coexistence measures as packages involving both detection and mitigation. The present document, however, follows ETSI TR 103 319 [i.21] in distinguishing, in each of these methods, a detection element and a mitigation element, and discussing these separately.

With all of the techniques described in the following clauses, it should be remembered that there may be a need to pay special attention to cross border co-ordination for countries with and without road tolling/radar.

6.2 Measures to enable coexistence of RLAN and road tolling (TTT) technologies

6.2.1 Detection of road toll stations

6.2.1.1 Overview

As a result of previous studies, CEPT Report 57 [i.5] and ECC Report 244 [i.7] list approaches for coexistence between TTT and RLAN. In this clause, detection part of these approaches will be discussed. All approaches detailed in the above two reports are covered by this clause. In addition, it is also considered how similar detection techniques have been implemented to enable sharing between ITS and Road tolling technologies, as made available in ETSI TS 102 792 [i.22].

Detection methods can be divided into the following categories:

- Detectors monitor a frequency band and report whether it is used or not. Usually, the interfering technology monitors the frequency band of the victim technology (for energy above a certain threshold or presence of a carrier signal see clause 6.2.1.2), but it is also possible to monitor other frequencies where the frequency use is correlated with the victim technology (see clause 6.2.1.3).
- Beacons are transmitted specifically for the purpose of protecting the victim technology. This requires the interfering technology to be able to receive and react on beacons (see clauses 6.2.1.4 and 6.2.1.5).
- Geo-location methods aim at detecting a spatial closeness between victim and interferer by the exchange of geographic information. This is usually realized by localization and look-up of stored locations from a database of fixed victim positions (see clauses 6.2.1.6 and 6.2.1.7).
- Country determination capability establishes whether the interfering technology is authorized to operate in a given country and prevents it from using the victim technology's frequency band unless is it located in a country where such operation is authorized. (see clause 6.2.1.8).

The detection methods described in the following are concrete instances of the aforementioned categories.

6.2.1.2 Road toll detector (basic energy detection)

A road toll detector tries to directly detect the road tolling signal via energy detection or carrier sensing on the road tolling frequencies. The road toll detector should have a range that is greater than the radius of the protection zone. There may be a possibility for different requirements being applied to WAS/RLAN access points and those devices associated with the access point for the purpose of Road toll detection.

6.2.1.3 Road toll detector (road toll protocol detector)

One of the detection options is the road toll detector within the WAS/RLAN equipment. A road toll detector is added to the WAS/RLAN device. To avoid false alarms (triggering coexistence mode) when not needed, the detected signal should be a road toll signal, just a simple power detector is not enough. The road toll detector should have a range that is greater than the radius of the protection zone. There may be a possibility for different requirements being applied to WAS/RLAN access points and those devices associated with the access point for the purpose of Road toll detection.

6.2.1.4 Detection of RLAN beacons transmitted by the road toll site.

One beaconing possibility to signal the presence of road tolling is to generate IEEE Std. 802.11™-2016 [i.2] beacons on channel 161 (5 795 MHz to 5 815 MHz), which covers the same band as road tolling. RLAN devices should activate mitigation techniques upon reception of a beacon frame. It is unclear how the frequencies can be used for road tolling and RLAN beaconing at the same time. The duty cycle and/or the power of RLAN beaconing is defined in order to protect road tolling from beaconing.

6.2.1.5 Specific RLAN beacons for coexistence

One beaconing possibility to signal the presence of (mobile) road tolling or enforcement is to generate specific beacons on a specific RLAN channel which would be in a different RLAN channel to the road tolling transmitters. The power level of the beacon would have to be enough to ensure that the detection range is greater than the radius of the protection zone. RLAN devices should activate mitigation techniques upon reception of a beacon frame. This may solve the problem highlighted above if the RLAN beacon is transmitting on the same transmit channel as road tolling. Another possibility is to use the same beacons that may be there to enable sharing between ITS and Road tolling - however these beacons are not mandatory and not needed for existing tolling locations, which are registered in a geolocation database.

This technique would require each tolling location to be equipped with an RLAN beacon. This technique requires that the beacons are understood by all RLAN devices regardless of manufacturer and technology standard or version. It is also required that receiving RLAN devices permanently store the protected zone information until the end date given in the beacon message, so that the beacon does not have to be permanently active.

6.2.1.6 Geo-location database (automatic detection)

A geo-location database defines protected zones where the victim technology (road toll stations) should be protected.

A version of this detection option that is implemented by ITS is the protected zone database. All road toll station positions are stored locally in a memory in the ITS station. Similar information would have to be stored and acted upon by the WAS/RLAN stations. The source of this data base is downloadable using the internet and can be updated periodically using software updates. The WAS/RLAN device would be equipped with a positioning device. If the RLAN device is a mobile device, it might have GNSS capability built-in. If the RLAN device is a stationary access point, then the position could be determined with the help of a connected mobile device that provides the GNSS position during configuration. When the GNSS position is close to a road toll station the mitigation mode is activated, e.g. RLAN switches to another channel.

A protected zone is defined by a centre position (geographic coordinates) and a protected zone radius. The protected zone radius should be at least the required separation distance where interference is not harmful. The separation distance depends on the output power of the WAS/RLAN device and these would have to take account separation distances presented in ECC Report 244 [i.7].

The database for fixed road tolling sites is managed and updated by ASECAP, the European Association of Operators of toll road infrastructures.

6.2.1.7 Geo-location database (manual adjustment)

This method shares the following concepts and tools with geo-location database (automated detection): A geo-location database is established that defines protected zones where road toll stations should be protected. A protected zone is defined by a centre position and a protected zone radius. Within each protected zone, mitigation methods are activated to protect the victim technology.

Here the tasks to protect victim technology is not a technical requirement of WAS/RLAN devices but are specified by regulations under light licensing model and performed manually by WAS/RLAN station operator. The light licensing model requires a station operator to notify the regulator before starting operation. The operator first establishes geographical coordinates of an intended location of its WAS/RLAN device. Then the operator compares the coordinates of its own WAS/RLAN device manually with the protected zones in the geo-location database. The database is available online, usually in a user-friendly form, such as web interface which indicates to the operator whether an WAS/RLAN device may operate in a location defined by geographic coordinates and whether activation of mitigation method(s) is required. Eventually, the operator installs the WAS/RLAN station, activates it and activates the mitigation method as applicable.

This method could enable coexistence with updated/new road toll stations, but only if combined with a suitable alert mechanism. The prerequisite is that an alerting authority (typically, the regulator) holds contact details of station operators, who have registered stations based on light licensing model. When road toll stations are going to be put in operation in a location, the alerting authority sends an alert to operators of the concerned WAS/RLAN stations to activate mitigation measures within a certain deadline. Another alert informs the operators that mitigation measures may be de-activated. It is also a prerequisite that WAS/RLAN station operators follow the instructions within the necessary time frame given by the alerting authority.

Within the light licensing scheme, the regulator might issue an "activation token" to the WAS/RLAN operator upon successful registration. This token contains a certificate with an electronic signature that can be used by the WAS/RLAN operator to activate the use of the band in its WAS/RLAN device(s). The certificate could be provided as a file for download into the configuration app of the WAS/RLAN device or as a QR code to the user. The validation of the certificate by the WAS/RLAN device could use existing public key infrastructures. Only after successful validation, the WAS/RLAN device (e.g. access point) starts using the band. This way, the registration process would be kept manual, but the activation of the band has a technical part involving the WAS/RLAN device. This concept would require agreement between the national regulatory authorities and the device manufacturers in order to standardize the implementation of such a process.

Geo-location database with manual adjustment is not a technique suitable for mobile RLAN stations, because those stations would require continuous supervision by the RLAN station operator.

6.2.1.8 Country Determination Capability (CDC)

ECC Report 330 [i.18] introduced a new mitigation approach based on a Country Determination Capability (CDC), which is a "functionality implemented on the device which aims to decide if the device is allowed or not to use the spectrum depending on the current country location of the device and its regulatory framework".

This technique could be used to indicate if WAS/RLAN use is allowed in a country. Devices capable of transmitting greater than 25mW EIRP would be expected to contain country determination capability.

During the development of ECC Report 330 [i.18] it was concluded that further granularity would be required to take into account that only part of this frequency range needs to be clear from WAS/RLAN use for the protection of TTT services and subsequently the 5 725 MHz to 5 850 MHz band was sub-divided into four sub bands: 5 725 MHz to 5 735 MHz, 5 735 MHz to 5 795 MHz, 5 795 MHz to 5 815 MHz and 5 815 MHz to 5 850 MHz. Therefore, manufacturers of devices wishing to offer maximum flexibility would be advised to implement these sub-bands within their CDC functionality.

6.2.2 Mitigation methods to reduce interference to road tolling (TTT)

6.2.2.1 Overview

In this clause, the mitigation part of the coexistence approaches will be discussed. Previous studies in CEPT Report 57 [i.5] and ECC Report 244 [i.7] suggested that for mitigation the TTT frequencies are "not available for WAS/RLAN use" upon detection, i.e. the actual mitigation part is to vacate the TTT frequencies. In the present document further mitigation methods are investigated, which results in the following categorization:

- Vacating a channel / frequency non-use (see clause 6.2.2.2).
- Change of transmit parameters:
  - Output power limitation (clause 6.2.2.3).
  - Duty cycle limitation (clause 6.2.2.4).

6.2.2.2 Vacate / frequency non-use

Vacating a channel upon detection is a method to protect a victim technology by not using the frequency band in which interference is harmful. This method can be combined with a signal detector or beacon detector, with a geo-location database, or with country determination capability.

The core requirement is that road tolling frequency band is vacated immediately upon detection. It is also required that WAS/RLAN uses a detection method before using the frequency band.

The vacate period, i.e. duration of frequency non-use, is dependent upon the detecting method:

- For CDC, the vacate period ends when the WAS/RLAN device detects it is no longer located in a country where it is not authorized to use the road tolling frequency band.
- For geo-location database (manual detection), the vacate period ends when the WAS/RLAN is no longer inside a protected zone, because the operator has moved the device, or a (temporary) protection zone has been cancelled and the device may start using the road tolling band again.
- For geo-location database (automatic detection), the vacate period ends when GNSS positioning indicates the WAS/RLAN is no longer inside a protected zone.
- For the remaining detection methods, vacate period will depend on detection frequency (detector sampling period, beacon interval), detection probability, protection criteria related to the characteristics of protected technology, such as road tolling transaction periods, inter-frame spacing etc., and on other assumptions. Examples of these considerations are provided in clause 6.4.1 of ETSI TR 103 319 [i.21].

In addition to the road tolling channel, which will always be subject to the vacate / frequency non-use method, the size of any necessary guard band also could be investigated as appropriate.

6.2.2.3 EIRP level reduction.

EIRP level reduction is a method of switching to using lower transmit powers upon detection in order to reduce interference to a level that is tolerable by the victim technology or power levels that are exempt from any need for mitigation techniques due to max power limitation that is below that of the existing SRD regulations (i.e. 25 mW total EIRP).

6.2.2.4 Duty cycle limitation

Duty cycle limitation describes a method of using a channel with only a limited duration per unit of time in order to leave the victim technology unaffected during the rest of the time. This is usually defined by a maximum duration of uninterrupted channel occupancy (T_{on}) and a dependent minimum idle duration (T_{off}). This method can under certain circumstances reduce the impact of interference, provided that the interfering technology leaves so much idle time to the victim technology that the major fraction of the communication is unaffected and losses due to interference do not exceed a tolerable maximum (i.e. do not cause harmful interference).

A detailed analytical investigation to support this is included in clause 6.4.3 and annex A of ETSI TR 103 319 [i.21].

6.3 Measures to enable coexistence of WAS/RLAN and Radar Operations

6.3.1 Detection of Fast Frequency Hopping (FFH) radar stations

6.3.1.1 Overview

Outcomes of statistical study between WAS/RLAN and frequency hopping radars in the 5 725 MHz to 5 850 MHz frequency band conducted during WRC-19 preparation under Agenda Item 1.16 (document reference ITU-R WP5A Contribution 1031 (2015-2019) [i.20]), concluded that the currently available DFS standards are not designed to deal with fast frequency hopping radars. This study only analysed the probability that the current DFS standards will be able to detect the radar signal. The identification phase has not been studied. Even if the radar signal is detected, this does not mean that the identification phase will be successful. A further study is required to validate the second step.

Additionally, it is noted that the CEPT position for Agenda Item 1.16 (WRC-19) agreed that the existing DFS techniques at 5 GHz have not been designed to protect all the operating modes of frequency hopping radars that are used in some CEPT countries in the 5 725 MHz to 5 850 MHz band. At this stage, current DFS requirements contained in both ETSI EN 301 893 [i.4] and ETSI EN 302 502 [i.29] as well as the parameters contained in Recommendation ITU-R M.1652-1 [i.3] for DFS are not sufficient to protect all FFH radar operating modes, although other modes used by these fast frequency hopping radars are covered by implementations of DFS in current ETSI standards.

The present document examines among radar detection methods only those techniques intended specifically to provide possible sharing solutions between WAS/RLAN and FFH radar modes not covered in DFS algorithms today. DFS as included in currently available standards is not the subject of examination in the present document. Instead, two categories of detection techniques will be discussed:

- Geo-location methods, which aim at detecting a spatial closeness between victim and interferer by the exchange of geographic information. This is usually realized by localization and look-up of stored locations from a database of fixed victim positions (see clauses 6.3.1.2 and 6.3.1.3).

- Country determination capability, which establishes whether the interfering technology is authorized to operate in a given country and prevents it from using the victim technology's frequency band unless is it located in a country where such operation is authorized (see clause 6.3.1.4).

6.3.1.2 Geo-location database (automated detection)

A geo-location database defines protected zones where the victim technology (radar stations) should be protected.

A protected zone is defined by a centre position (geographic coordinates) and a protected zone radius or by a protected area such as military proving ground and a protected range around the protected area's perimeter. The protected zone radius or protected range should be at least the required separation distance where interference is not harmful. The separation distance depends on the output power and operating restrictions of the WAS/RLAN device. The protected zone can cover the entire territory of a CEPT country, which would effectively be the same as a "No" entry in the country table within ECO Report 06 [i.28] on Country Determination Capability.

Automated detection version of geo-location database assumes that all radar station positions are stored locally in a memory in the WAS/RLAN station. The source of this data base should be downloadable using the internet and can be updated periodically using software downloads. The WAS/RLAN station would have to be equipped with a GNSS positioning device. When the WAS/RLAN position is within an identified radar exclusion zone then a suitable co-existence mode is activated. An analogous detection method has been introduced in clause 6.2.1.6 for coexistence among WAS/RLAN and road toll stations. This type of detection may not be feasible to enable co-existence with temporary and mobile radar stations due to security concerns and due to the fact that its effectiveness would depend upon periodicity of the software update cycle for the database information.

6.3.1.3 Geo-location database (manual adjustment)

This technique shares the following concepts and tools with geo-location database (automated detection): A geo-location database is established that defines protected zones where radar stations should be protected. A protected zone is defined by a centre position and a protected zone radius, or by a protected area and a protected range. Within each protected zone, mitigation method(s) are activated to protect the victim technology (e.g. radar stations).

In geo-location database (manual adjustment) the tasks to protect victim technology are specified by regulations under light licensing model and performed manually by WAS/RLAN station operator. The operator establishes geographical coordinates of an intended placement of WAS/RLAN device. Then the operator compares the coordinates with the geo-location database. The database is available online, usually in a user-friendly form, such as web interface which indicates to the operator whether an WAS/RLAN device may operate in a location defined by geographic coordinates and whether activation of mitigation method(s) is required. Eventually, the operator installs the station, activates it and activates the coexistence mode as applicable.

If combined with a suitable alert mechanism, this technique enables coexistence with temporary fixed and/or mobile radar stations. The prerequisite is that an alerting authority (typically, the regulator) holds contact details of station operators, who register stations in a light licensing model. When radar stations are going to be put in operation temporarily in a location, or mobile radar stations are going to be operated temporarily in an area, the alerting authority sends an alert to operators of the concerned WAS/RLAN stations to activate mitigation measures within a certain deadline. Another alert informs the operators that mitigation measures may be de-activated.

Geo-location databases with manual adjustment are regarded as not being a technique suitable for the protection of Radar installations from mobile RLAN stations, because the mobile RLAN stations would require continuous supervision by the RLAN operator.

6.3.1.4 Country Determination Capability (CDC)

ECC Report 330 [i.18] introduced a new mitigation approach based on a Country Determination Capability (CDC), which is a "functionality implemented on the device which aims to decide if the device is allowed or not to use the spectrum depending on the current country location of the device and its regulatory framework".

This technique could be used to indicate if WAS/RLAN use is allowed in a country. Devices capable of transmitting greater than 25mW EIRP would be expected to contain country determination capability.

The division of the 5 725 MHz to 5 850 MHz band into the four sub-bands, described in clause 6.2.1.8, was not seen as a requirement for the protection of FFH radars as these tend to require the whole band when deployed. Therefore, for the protection of FFH radars, country determination capability would be expected to be implemented across the whole of the 5 725 MHz to 5 850 MHz band.

6.3.2 Co-existence methods to reduce interference to Radar

6.3.2.1 Introduction

The usual mitigation method in protecting radars is to make frequencies "not available for WAS/RLAN use" upon detection, i.e. to vacate the WAS/RLAN channel or radar frequency(s) where the radar is operating. This is the same method that is being used by DFS as well. In addition to frequency non-use / vacation, the present document is also discussing EIRP level reduction as an alternative mitigation method.

6.3.2.2 Vacate / frequency non-use

Vacating a channel upon detection is a method to protect a victim technology by not using the frequency channel. This method can be combined with geo-location database approach to detection, or with country determination capability. As it originally stems from DFS, it can also be combined with DFS detection in a device (which will not be discussed in the present document).

For protecting radar by vacating the channel, the following should be considered:

- For CDC, the vacate period ends when the WAS/RLAN device detects it is no longer located in a country where it is not authorized to use the radar frequency band.
- For geo-location database (manual detection), the vacate period ends when the WAS/RLAN device is no longer inside a protected zone, because the operator has moved the device, or a (temporary) protection zone has been cancelled and the device may start using the radar band again.
- For geo-location database (automatic detection), the vacate period ends when GNSS positioning indicates the WAS/RLAN device is no longer inside a protected zone.
- While DFS may limit the vacate period / frequency non-use to the WAS/RLAN operating channel where a radar is detected, the detection methods (geo-location and/or CDC) included in the present document will result in vacating the whole of the 5 725 MHz to 5 850 MHz frequency band immediately upon detection.

6.3.2.3 EIRP level reduction

EIRP level reduction is a method of switching to using lower transmit powers upon detection in order to reduce interference to a level that is tolerable by the victim technology or power levels that are exempt from any need for mitigation techniques due to max power limitation that is below that of the existing SRD regulations (i.e. 25 mW total EIRP). This is achieved by use of the TPC functionality within the WAS/RLAN device.

7 Evaluation of measures to enable co-existence

7.1 Introduction

This clause focuses on evaluating the measures to enable co-existence highlighted in the respective parts of clause 6 of the present document.

7.2 Evaluation of measures to enable coexistence of WAS/RLAN and road tolling (TTT)

7.2.1 Introduction

The following detection and mitigation methods were considered as part of the present document to enable coexistence of WAS/RLAN and Road Tolling (TTT).

7.2.2 Detection of road toll stations

7.2.2.1 Overview

The following clauses evaluate the proposed detection methods for road toll stations detailed in clause 6.2 of the present document.

7.2.2.2 Road toll detector (basic energy detection)

Preliminary analysis in ECC Report 244 [i.7], annex 5 during coexistence studies at CEPT indicated that an energy detection threshold of the order of -100 dBm/500 kHz would be required for a reliable detection of road tolling.

Based upon feedback from the WAS/RLAN industry energy detection alone is not possible. WAS/RLAN devices measure the Signal to Interference plus Noise Ratio (SINR) only and implementations use SINR measurements to calculate Energy Detect by assuming a noise figure of -95 dBm/20 MHz. False detections occur as a level of -80 dBm is approached, based upon a 20 MHz bandwidth.

7.2.2.3 Road toll detector (road toll protocol detector)

Where a road toll detector is added to the WAS/RLAN device, such a feature should be resistant to being triggered by false alarms, (triggering coexistence mode) when not needed, i.e. the triggering signal should be a road toll signal. The road toll detector function would need a detection range greater than the radius of the required protection zone.

7.2.2.4 Detection of RLAN beacons transmitted by the road toll site.

RLAN beacons in the road tolling frequency band cause in-band interference. On toll plaza installations with several independent tolling lanes, tolling transactions are scheduled independently on separate channels and overlap in time. In this scenario, it is impossible to find time slots to insert RLAN beacons of 20 MHz bandwidth, because they overlap in time and interfere with all road tolling channels.

7.2.2.5 Specific RLAN beacons for coexistence

One possibility to signal the presence of (mobile) road tolling or enforcement is to generate specific beacons on a specific RLAN channel which would be in a different RLAN channel to the road tolling transmitters. To generate those beacons tolling stations would require RLAN transmitters. Furthermore, generic RLAN beacons would need to be specified that are understood by all RLAN devices regardless of manufacturer and technology standard or version.

Another option is the re-use of ITS coexistence beacons for RLAN. Those ITS beacons are fully specified through ETSI ITS standards. Data formats are described in ETSI EN 302 637-2 [i.30] (CAM standard) and in ETSI TS 102 894-2 [i.31] (Common Data Dictionary), the usage of beacons in the ITS context is specified in ETSI TS 102 792 [i.22] (ITS/TTT coexistence standard). At the time and preparation of the present document the channel from 5 895 MHz to 5 905 MHz is used to transmit ITS beacons with ITS-G5. This is used in conjunction with a geolocation database. This method is technology dependent and requires an IEEE 802.11™ [i.2]based receiver that is continuously listening to a 10 MHz ITS-G5 channel and a CAM decoder on the interferer's side.

RLAN and ITS beacons are not suitable for broadcasting at toll plazas, where several CEN DSRC RSUs are operated independently. In these toll plazas the CEN DSRC transactions overlap in time and there is no fixed schedule with guaranteed idle time slots, in which beacons can be broadcast. If beacon transmitters are directly located at a toll plaza, they have to be operated with reduced transmit power and reduced transmit rate in order to meet coexistence requirements. A reduced transmit rate of beaconing and a reduced transmit power still does not guarantee interference free operation between the beacons and TTT and it lowers the probability of detection by RLAN in the vicinity of the tolling station.

On the victim's side, it requires transmitter installations on each tolling station. It should be noted, that for coexistence of ITS with tolling, the ITS beacon transmitters are not required to be installed at the same locations as tolling stations, since the geo-location information is contained within the beacon messages. Beacon transmitters co-located with tolling stations bear the risk of interference. The protection of tolling from ITS can be achieved by placing ITS beacon transmitters hundreds of meters, even up to a few kilometres ahead of a tolling station, so that ITS equipped vehicles receive protected zone information before they reach a tolling station and are able to activate mitigation techniques in time. In such separated deployment ITS beacons are not detectable at the location of the tolling station, and thus the tolling station cannot be protected from RLANs in their vicinity.

Beacons could be used in conjunction with a database (see clause 7.2.2.6 below) where certain TTT devices are not covered by the database. RLAN beacons could be a solution to protect special types of road tolling devices like temporary and mobile road tolling, smart tachograph or weight and dimensions applications. These temporary and mobile TTT devices could be equipped with their own RLAN beacon to activate co-existence measures to protect the mobile road toll station. It should be noted that ITS beacons are not required for coexistence of ITS with smart tachograph or weight and dimensions applications.

Beacons are not required for existing road tolling installations, which are registered in the geo-location database. Its use for RLAN coexistence would require an installation of new equipment at thousands of locations in Europe, and the role and responsibility for this effort is not clear.

7.2.2.6 Geo-location database (automatic detection)

The use of a geo-location database with automated detection is an effective method to protect long term road toll installations. At the same time, it allows to re-use the frequency by WAS/RLAN outside protected zones. Protected zones will cover only a small fraction of the land area in Europe.

As an example, the Czech Republic has assigned 60 protected zones for road tolling with 1,8 km radius (see ECC Report 330 [i.18]), which altogether cover slightly less than 1 % of the land area of Czech Republic (which is 78,871 km^2). The geo-location database in combination with frequency protection allows coexistence by spatial separation. The road tolling community has established the corresponding database. Protected zones have to be further investigated and in case of WAS/RLAN the role and responsibilities of stakeholders would have to be clearly defined.

Detection can be performed by a table lookup and comparison to the WAS/RLAN's own geographical location, which can be determined automatically. WAS/RLAN usually have Internet access that enables database updates.

The geo-location database cannot cover tolling enforcement vehicles unless the whole road network (subject to tolling) is included in protected zones.

There is no technology lock in, i.e. the method does not depend on the interfering technology.

A geo-location database approach would be dependent upon the accurate localization of WAS/RLAN transmitters operating in the road tolling bands. Further consideration of how localization could be achieved, especially with regards to indoor equipment, is required. Security measures would also need to be addressed to prevent user modification of the localization and disabling of mitigation although this security concern would be common to all mitigation techniques.

The economic viability of providing a database has been questioned but it has been noted that there may be possibilities to leverage existing databases. As an example, for the coexistence between ITS and road tolling, ASECAP operates a European database of protected zones, which the car manufacturers use in their ITS OBU's.

It may not be feasible to use a geo-location database with automatic detection to enable co-existence with temporary and mobile road tolling, smart tachograph or weights and dimensions applications. In these cases, the WAS/RLAN station may also have to implement an additional method to protect these special types of road tolling devices. One possible solution would be for these temporary and mobile TTT devices to be equipped with their own RLAN beacon (see clause 7.2.2.5) or have a power level high enough to trigger surrounding WAS/RLAN stations to activate co-existence measures to protect the mobile road toll station.

7.2.2.7 Geo-location database (manual adjustment)

The use of a geo-location database with manual adjustment is a regulatory measure based on using a geo-location database to protect long term road toll installations. It is a regulatory method that mandates the WAS/RLAN station operator to manually identify whether the equipment is located within a protected zone. Identically to geo-location database with automated detection, it allows to re-use the frequency by WAS/RLAN outside protected zones.

Protected zones will cover only a small fraction of the land area in Europe. As an example, the Czech Republic has assigned 60 protected zones for road tolling with 1,8 km radius (see ECC Report 330 [i.18]), which altogether cover slightly less than 1 % of the land area of Czech Republic (which is 78,871 km^2).

The geo-location database with manual adjustment in combination with frequency protection allows coexistence by spatial separation. Similar to geo-location database with automated detection, this method depends on the availability of up-to-date database of road toll installation positions, and it strongly depends on the compliance of the WAS/RLAN station operators to follow the regulation and/or effective enforcement. Stakeholder responsibilities for collecting and updating the data and maintaining the database would have to be defined, but also the responsibility to use the data by the WAS/RLAN station operators.

In contrast to geo-location database with automated detection, this method depends upon compliance of the WAS/RLAN station operator. It does not include technical requirements on WAS/RLAN transmitters operating in the road tolling bands to be able to automatically determine whether the WAS/RLAN transmitter is located within the protection zone. Thus, there are no testable requirements that could be defined in a harmonised standard. Unintended use is technically not prevented by the device itself. Consequently, this measure cannot be observed or enforced by market surveillance, but only by monitoring the WAS/RLAN usage. The idea of monitoring frequency band usage by automatic measuring probes, which are WAS/RLAN receivers placed within protected zones, is described in ECC Report 330 [i.18].

Only if combined with a suitable alert mechanism, this method could enable coexistence with updated and/or new road toll station locations. This requires that WAS/RLAN station operator contact details be available to the alerting authority and that WAS/RLAN station operators follow the instructions within the necessary time frame given by the alerting authority.

This method cannot cover mobile enforcement vehicles unless the whole road network (subject to tolling) is included in protected zones.

There is no technology lock in, i.e. the method does not depend on the interfering technology.

7.2.2.8 Country Determination Capability (CDC).

The ability of country determination capability to successfully achieve its aims relies upon two aspects:

- the ability for the WAS/RLAN transmitter to know in which country it is located; and
- up to date information regarding the regulatory status of WAS/RLAN usage in CEPT member states.

It should be noted that ECC Report 330 [i.18] assumes that the default condition is that WAS/RLAN operation is not allowed in any CEPT member state. This default condition is the one that is expected to apply unless both above bullet points are satisfied.

For the WAS/RLAN transmitter to know in which country it is located, the accuracy provided by GNSS is not required, but could be an option, especially for outdoor systems. However other solutions, especially for indoor systems, can provide the location accuracy required for CDC.

In all cases the location data should not be modifiable by the end user. This is to ensure compliance with the applicable regulatory framework.

In terms of the information regarding the regulatory status of each CEPT member state, ECC Report 330 [i.18] recommends that ECO maintains national regulatory information which is currently provided in ECO Report 06 [i.28]. This report is available in the usual PDF format used for all ECC/CEPT deliverables as opposed to a machine-readable format. A machine-readable version may be available in the future.

In addition to the regulatory status of each country, ECO Report 06 [i.28] also contains a link to the national regulations applicable in those countries that allow WAS/RLAN usage in all or part of the 5,8 GHz band. These national regulations will detail the technical conditions for WAS/RLAN operation within that country.

It is also expected that upon changes to the regulatory status of a CEPT member state recorded in ECO Report 06 [i.28], manufacturers may be expected to update existing WAS/RLAN equipment. This may be achieved by issuing software/firmware updates.

7.2.3 Mitigation methods to reduce interference to road tolling devices.

7.2.3.1 Overview

Vacate/frequency non-use, transmit power control, duty cycle limitation and packet by packet operation as detailed in clause 6.2.2 are discussed in the clauses below.

In addition, the time duration of protection is a parameter for the mitigation strategy, which has to be considered in the specification of each mitigation method. Mitigation should be active for a multiple of the detection frequency, and at least until the detector gives a negative answer with high reliability.

7.2.3.2 Vacate / frequency non-use

Vacating a channel / frequency non-use is the most effective method for protecting the victim technology.

In the case of road tolling, only a small portion of the land area is affected by protected zones, where the road tolling frequency band should not be used by WAS/RLAN, see clause 7.2.2.6.

There is no technology lock in, i.e. the method does not depend on the interfering technology.

7.2.3.3 EIRP level reduction (Transmit power control)

The tolerable transmit power limit calculated in ETSI TR 103 319 [i.21], clause 6.4.2 is so low that the road tolling frequencies are actually not useable for WAS/RLAN within the vicinity of the road toll stations. It is proposed that future work should be based upon actual interference effects and measurements rather than assumed I/N ratio (taking into account separation distances, WAS/RLAN power levels, WAS/RLAN Energy detection thresholds, etc.).

7.2.3.4 Duty cycle limitation

The tolerable duty cycle calculated in ETSI TR 103 319 [i.21], clause 6.4.3 is so low that the road tolling frequencies are actually not useable for WAS/RLAN within the vicinity of the road toll stations. This is further supported by the analytical investigation in annex A and related discussion below.

Interference mitigation to CEN DSRC road tolling by duty cycle restriction is possible, as has been reported in ETSI TR 102 960 [i.17] and specified in ETSI TS 102 792 [i.22] to mitigate interference into CEN DSRC caused by ITS transmitters. However, as has been shown in ETSI TR 103 319 [i.21] (see clause 6.4.3 and annex A therein), the duty cycle limit arising from ETSI TS 102 792 [i.22] results in values below 5 %, even for a single interferer, and can go down to well below 1 % in the case of several interferers.

Since WAS/RLAN is causing in band interference to TTT-DSRC, the duty cycle limits as calculated in ETSI TR 103 319 [i.21] are even stricter. In the evaluated MLFF example in clause A.4.2.1 of ETSI TR 103 319 [i.21], even a single interferer should not transmit with more than 0,4 % duty cycle to avoid harmful interference to the TTT-DSRC RSU receiver.

For toll plazas with independent toll lanes, the interference limits are more relaxed, also because of the lower driving speed. Consequently, for open toll lanes an overall duty cycle limit of 5 % will be sufficient for most use cases (see table A.5 in ETSI TR 103 319 [i.21]) and for tollgates with barriers all interfering transmitters should not exceed a total duty cycle of 20 % for most use cases (see table A.6 of ETSI TR 103 319 [i.21]). Note that an overall duty cycle limit holds for all WAS/RLAN devices in the vicinity of a toll station.

Based upon the above, duty cycle restriction would limit the use of WAS/RLAN in vicinity of MLFF and open tollgates to very few use cases, while in the vicinity of a tollgate with a barrier around 20 % of the channel capacity could be shared with WAS/RLAN and other applications in 5 795 MHz to 5 815 MHz. Usually, almost all toll plazas have also open toll lanes and not only lanes with a barrier. Therefore, the possible duty cycle sharing scenarios are rare.

7.3 Evaluation of measures to enable coexistence of WAS/RLAN and Radar

7.3.1 Introduction

The following detection and mitigation methods are considered as part of the present document to enable coexistence of WAS/RLAN and certain modes of fast frequency hopping radar.

7.3.2 Detection of radar stations

7.3.2.1 Overview

In the current ETSI Standards, radar detection is performed as part of the DFS functionality. This relies upon the WAS/RLAN being able to detect a particular signal pattern and know that it is a radar and that it should move away from that channel within a defined time and not re-use that channel for a defined amount of time. This process is dependent upon the characterization of the radar signature within the aforementioned standards. The issue with fast frequency hopping radars is that they may have moved channel before the WAS/RLAN has detected their presence.

Where DFS functionality is unable to detect signals emitted by fast frequency hopping radars, an alternative to detecting "live" signals is to use a geo-location method, whereby the WAS/RLAN interrogates a database (either automatically or manually) that contains details of the locations of radars and their exclusion zones enabling the WAS/RLAN to determine whether transmission is possible. Alternatively, CDC could be used to prohibit use within the entire territory of a CEPT member state.

The following clauses evaluate the proposed detection methods for radar stations detailed in clause 6.3 of the present document.

7.3.2.2 Geo-location database (automatic detection)

In theory the use of an automatic geo-location database should be an extremely effective method of mitigating the risk of interference from WAS/RLAN to radars. However, this effectiveness assumes two key factors:

- All radar locations are always detailed accurately within the database.
- All WAS/RLAN devices can geo-locate with sufficiently accuracy that enables them to determine whether or not they are inside the radar's exclusion zone.

Taking the first point, the issues here relate to the temporary use of transportable radars which by their nature are moved to a specific location, used for a relatively short period of time, before being moved again. Will the database be updated and interrogated sufficiently frequently to capture these operational location changes? The other issue is related to the access to information on the location of military radars knowing that this information is generally not in the public domain.

In terms of the WAS/RLAN devices knowing its location, it is a case of deciding whether the technique used for location determination provides sufficient resolution to enable the appropriate degree of mitigation of the interference risk.

7.3.2.3 Geo-location database (manual adjustment)

The use of a geo-location database with manual adjustment may be an effective method to protect long-term fixed radar installations or geographic areas where mobile radar stations are being used, such as military proving grounds.

The geo-location database with manual adjustment in combination with frequency protection allows coexistence by spatial separation. This technique allows to re-use the frequency by WAS/RLAN outside protected zones.

This technique depends on the availability of up-to-date database of radar installation positions and/or of protected geographic areas. Stakeholder responsibilities for collecting and updating the data and maintaining the database would have to be defined, noting that access to information on the location of military radars is generally not in the public domain.

In contrast to geo-location database with automated detection, this technique does not require WAS/RLAN transmitters operating in the radar bands to be able to automatically detect the transmitter's precise location, as localization is performed by WAS/RLAN station operator. On the other hand, the success of geo-location database with manual adjustment does depend on operator compliance.

If combined with a suitable alert mechanism, this technique enables coexistence with temporary fixed and/or mobile radar stations. This requires that WAS/RLAN station operator contact details be available to the alerting authority.

7.3.2.4 Country Determination Capability (CDC)

The ability of country determination capability to successfully achieve its aims relies upon two aspects:

- the ability for the WAS/RLAN transmitter to know in which country it is located; and
- up to date information regarding the regulatory status of WAS/RLAN usage in CEPT member states.

It should be noted that ECC Report 330 [i.18] assumes that the default condition is that WAS/RLAN operation is not allowed in any CEPT member state. This default condition is the one that is expected to apply unless both of the above bullet points are satisfied.

In terms of the WAS/RLAN transmitter knowing in which country it is located, the accuracy provided by GNSS is not required, but could be an option, especially for outdoor systems. However other solutions, especially for indoor systems, can provide the location accuracy required for CDC.

In all cases the location data should not be accessible to the end user to ensure correct operation within the applicable regulatory framework.

In terms of the information regarding the regulatory status of each CEPT member state, ECC Report 330 [i.18] recommends that ECO maintains national regulatory information which is currently provided in ECO Report 06 [i.28]. This report is available in the usual PDF format used for all ECC/CEPT deliverables as opposed to a machine-readable format. A machine-readable version may be available in the future.

In addition to the regulatory status of each country, ECO Report 06 [i.28] also contains a link to the national regulations applicable in those countries that allow WAS/RLAN usage in all or part of the 5,8 GHz band. These national regulations will detail the technical conditions for WAS/RLAN operation within that country.

It is also expected that upon changes to the regulatory status of a CEPT member state recorded in ECO Report 06 [i.28], manufacturers may be expected to update existing WAS/RLAN equipment. This may be achieved by issuing software/firmware updates.

With country determination capability, it is a simple yes/no answer as to whether a WAS/RLAN device may operate or not. This would prove effective in preventing interference and do so without the need to provide extra overheads such as databases of radar installations, permanent or temporary.

However, it does have the drawback of sterilizing the frequency band/sub-bands in question within an entire country when radar usage may be extremely limited.

7.3.3 Mitigation techniques to reduce interference to Radar

7.3.3.1 Vacate/frequency non-use

In terms of reduction of interference, vacating a channel or cessation of transmission on a channel that is being used by a radar will stop the interference.

7.3.3.2 EIRP level reduction (Transmit power control)

In terms of reduction of interference, EIRP (i.e. transmit power) reduction may prevent the radar being interfered with. However, this will depend upon other factors such as the level of power reduction and the proximity of the WAS/RLAN device to the victim radar.

Therefore, this technique may work in some cases, especially if combined with other measures such as the creation of exclusion zones based upon geo-location techniques.

7.4 Summary

Ideally any new mitigation measures would need to address both co-existence with FFH Radar and TTT systems. This is despite geographic differences in their deployment. The drawback with this approach is that some of the measures discussed in the present document are better suited to solving the coexistence issues around one of the incumbents than the other. Whatever measure is used, the result needs to be that the WAS/RLAN device is the party that alters its behaviour and not the TTT or radar system.

The use of databases to store location information of potential interference victims, relies upon those databases having complete and accurate information and being readily accessible by all systems that require the information. After consideration, the use of updatable online databases may work for TTT systems, but is probably not suitable for military radars, especially transportable/temporary radars, given the potential security concerns that this information may pose.

As the mandatory use of DFS in bands below 5 725 MHz successfully protects many radars from interference, it is tempting to believe that expanding DFS functionality to cover all operating modes of all radars would provide the ideal solution for the protection of radar operation. However, expanding DFS to include all modes of all radars for the 5 725 MHz to 5 850 MHz band, may never be technically achievable or even desirable when viewed from an electronic warfare perspective and the operational need for these radars to operate stealthily at times.

Considering the above and noting that the ECC has published ECC Report 330 [i.18], Country Determination Capability (CDC) offers the most effective level of interference mitigation for the minimum development expenditure. CDC does provide interference mitigation for both TTT and radar deployments and thus only requires manufacturers to implement one interference mitigation feature.

Annex A: Background information

A.1 Background on measures to enable coexistence of TTT and ITS

As a background for the study of coexistence of WAS/RLAN and road tolling, this clause describes the implemented mitigation technique between ITS and road tolling.

Because of the small frequency separation between the bands 5 795 MHz to 5 815 MHz and 5 855 MHz to 5 925 MHz and the fact that both systems operate in the road traffic environment, there is a significant potential for interference. In ECC Report 101 [i.37], ECC Report 228 [i.38], ETSI TR 102 654 [i.39] and ETSI TR 102 960 [i.17] it has been concluded that:

- CEN DSRC transmissions do not cause any significant interference to ITS stations.
- Some mitigation techniques that are specified in the present document degrade the performance of ITS stations.
- The transmit signal from ITS stations can cause blocking at the receiver in a CEN DSRC RSU.
- Unwanted emissions from ITS stations can cause interference at the receiver in a CEN DSRC RSU.
- The transmit signal from ITS stations can cause interference at the receiver in a CEN DSRC OBU in vehicles.
- Therefore, technical solutions are required to minimize interference to tolling CEN DSRC RSU and OBU and to minimize the performance degradation of ITS.

For ITS stations, this can be achieved either by always complying with some transmit restrictions (coexistence mode, see ETSI TR 103 319 [i.21], clause 5.4) or by receiving and processing information on the position of CEN DSRC tolling stations and complying to transmit restrictions in the immediate vicinity of the CEN DSRC tolling station (protected zone, see ETSI TR 103 319 [i.21], clause 5.2). The goal is to restrict the unwanted emissions of an ITS station within the vicinity of a CEN DSRC tolling zone.

The ITS bands 5 855 MHz to 5 925 MHz are out-of-band compared with the TTT band 5 795 MHz to 5 815 MHz. Because the ITS transmitter antenna can come very close to the sensitive road toll receiver antennas (as close as one meter) studies have shown that road toll systems will be interfered, even if the two different bands are not overlapping. To protect road toll installations against interference from ITS a mitigation technique is implemented according to ETSI TS 102 792 [i.22].

To enable a lot of users in one channel, the ITS transmitters are transmitting with a low duty cycle. Typically, a message is transmitted 1 to 10 times each second with a message length of 1 ms. One single ITS transmitter will not interfere with a road toll system, several ITS transmitter closely located to a road toll station are necessary for interference. To achieve flexible solutions, four different coexistence modes are allowed by the ITS station. The different modes are made of a combination of reduced output power and reduced duty cycle.

The most difficult part of the mitigation technique is the detection, i.e. how does the ITS station know where the road toll stations are located. There are two possible options, one of which is always used:

- One of the detection options is the road toll detector. A road toll detector is added to the ITS station, normally the same antenna is used. To avoid false alarms, triggering coexistence mode when not needed, the detected signal should be a road toll signal, just a simple power detector is not enough. The road toll detector has a limited range, this reduces the error of positioning. Because the detector has limited range, shorter than the radius of the protection zone, the ITS station transmits the road toll detection in an ordinary ITS CAM message. ITS stations using road toll detectors are also alert for CAM messages with road toll information. This means that there is a risk that one single ITS station will switch to coexistence mode too late, however, as described above, it is only when several transmitting ITS station are close to the road toll station that there is a risk for interference.

- The other detection option is the protected zone database. All road toll station positions are stored locally in a memory in the ITS station. The source of this data base is downloadable using the internet. The ITS station is equipped with a GNSS position device. When the position is close to a road toll station the coexistence mode is activated. Because of moving, temporary and new installed road toll stations, the ITS station should also be alert to road toll protection information in ordinary ITS CAM messages. If road toll stations are equipped with their own ITS beacon, then they can warn surrounding ITS stations to protect this road toll station. The ITS beacon should be designed in such a way that it does not interfere with the road toll station itself. This needs an agreement of road operators and car manufacturers, otherwise the ITS station needs to regularly update its internal protected zone database.

Annex B: Bibliography

- ETSI EN 302 663 (V1.2.1): "Intelligent Transport Systems (ITS); Access layer specification for Intelligent Transport Systems operating in the 5 GHz frequency band".
- Commission Decision 2005/513/EC of 11 July 2005 on the harmonised use of radio spectrum in the 5 GHz frequency band for the implementation of wireless access systems including radio local area networks (WAS/RLANs). .
- Commission Decision 2007/90/EC of 12 February 2007 amending Decision 2005/513/EC on the harmonised use of radio spectrum in the 5 GHz frequency band for the implementation of Wireless Access Systems including Radio Local Area Networks (WAS/RLANs).
- ECC/DEC/(04)08 ECC Decision 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) (30/10/2009).
- Resolution 229 (WRC-03, Rev. WRC-12): "Use of the frequency bands 5150-5250 MHz, 5250-5350 MHz and 5470-5725 MHz by the mobile service for the implementation of wireless access systems including radio local area networks".
- ETSI TS 136 211 (V13.3.0): "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation (3GPP TS 36.211 version 13.3.0 Release 13)".
- ETSI TS 136 101 (V11.17.0): "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception (3GPP TS 36.101 version 11.17.0 Release 11)".
- ETSI TS 136 104 (V13.5.0): "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception (3GPP TS 36.104 version 13.5.0 Release 13)".
- Commission Decision 2008/671/EC of 5 August on the harmonised use of radio spectrum in the 5875-5905 MHz frequency band for safety-related application of Intelligent Transport Systems (ITS).
- ECC Recommendation (08)01: "On the use of the band 5855-5875 MHz for Intelligent Transport Systems".
- Directive 2010/40/EU on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport.
- Standardisation mandate M/453 addressed to CEN, CENELEC and ETSI in the field of information and communication technologies to support the interoperability of cooperative systems for ITS.
- ETSI TR 103 083 (V1.1.1): "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".
- IEEE P802.11™ Wireless LANs (IEEE 802.11™-03/940r4, May 2004): "TGn Channel Models".
- Kenney, Barve, Rai, and Kanai: "Comparing Communication Performance of DSRC OBEs from Multiple Suppliers", ITS World Congress 2012.
- CEPT Report 59: "In response to the EC Permanent Mandate on the "Annual update of the technical annex of the Commission Decision on the technical harmonisation of radio spectrum for use by short range devices" Report approved on 17 June 2016 by the ECC".
- Commission Decision 2006/771/EC of 9 November 2006 on harmonisation of the radio spectrum for use by short-range devices.
- Recommendation ITU-R.1638: "Characteristics of and protection criteria for sharing studies for radiolocation, aeronautical radionavigation and meteorological radars operating in the frequency bands between 5250 and 5850 MHz".

History

Document history		
V1.1.1	May 2023	Publication