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TECHNICAL REPORT

Intelligent Transport Systems (ITS);
Mitigation techniques to avoid harmful interference between equipment compliant with ES 200 674-1 and ITS operating in the 5 GHz frequency range;
Evaluation of mitigation methods and techniques

Reference

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Keywords

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Intelligent Transport Systems (ITS).

Modal verbs terminology

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Executive summary

The present document is about mitigation techniques to avoid or lower harmful interference of ITS radio transmitters operating in the 5,9 GHz band upon 5,8 GHz backscatter communication systems used for e.g. electronic fee collection.

The present document comprises the evaluation of mitigation techniques specified in ETSI TS 102 792 [i.7] and their applicability for the High Data Rate - DSRC (HDR-DSRC) technology standardized by UNINFO in Italy and by ETSI ES 200 674-1 [i.1] used for road tolling.

As a global result it can be concluded that the mitigation techniques standardized in [i.7] for the CEN-DSRC technology (also referred to as Medium Data Rate - DSRC (MDR-DSRC), and recently named TTT DSRC as the term to be used in the future) are sufficient to avoid harmful interference to HDR-DSRC.

In order to perform the tests of which the results are reported in the present document, off-the-shelf equipment was used and no further calibration was performed. The transmit power of the ITS signal in the 5,9 GHz band could be tuned from 10 dBm EIRP to 23 dBm EIRP. The length of the ITS signals in terms of number of bytes could be adjusted within the limits allowed by this technology. The message repetition interval was set to either 10 ms or 100 ms. The HDR-DSRC system was operated with a test application (echo message of adjustable length), applying normal operational radio parameter settings (these could not be changed).

The performed measurements were compared with a statistical model presented in Annex A of the present document, which allows concluding whether the HDR-DSRC downlink, or the uplink, or both links are interfered. The performance results for the various test configurations with a single interferer and multiple interferers, both conducted in an anechoic chamber and in a real road environment, indicate that harmful interference is only on the HDR-DSRC downlink.

Coexistence scenarios were identified for HDR-DSRC, i.e. technical limits to mitigate harmful interference are:

- The ITS-SUs upper TX power limit is 14 dBm EIRP.
- The lower distance limit between a HDR-DSRC OBU and an ITS-M5 interferer transmitting with 23 dBm EIRP is 5 m.
- The ITS-M5 repetition interval of 100 ms is not resulting in harmful interference.

Introduction

With the birth of communications in the 5 GHz bands [i.2], [i.3], [i.4] for Intelligent Transport Systems (ITS) on the basis of the ITS station and communication architecture specified in [i.6] and [i.5] potential harmful interference caused by ITS equipment installed in vehicles on Electronic Fee Collection (EFC) and Electronic Toll Collection (ETC) installations (toll plazas) became obvious. Two major standardized Dedicated Short Range Communication (DSRC) technologies are used in Europe and other regions for EFC/ETC and other road transport related services, i.e. the CEN-DSRC technology standardized by CEN (also referred to as TTT-DSRC according to CEPT decision) and by ETSI in the European harmonised multi part standard ETSI EN 300 674-2-1 [i.11], ETSI EN 300 674-2-2 [i.12], and the High Data Rate - DSRC (HDR-DSRC) technology standardized by UNINFO in Italy and by ETSI ES 200 674-1 [i.1].

Both DSRC technologies operate in the same band at 5,8 GHz. Initial interference tests and simulations were performed for MDR-DSRC [i.8], and resulted in mitigation techniques standardized in [i.7]. These mitigation techniques were taken as basis for further investigations on HDR-DSRC.

The present document:

- complements [i.8] by presenting results of investigations on interference of 5,9 GHz ITS communications on the HDR-DSRC systems;
- recommends mitigation techniques with reference to [i.7]; and
- suggests running of an ETSI plug test dedicated to HDR-DSRC.

1 Scope

The present document reports about test executions and results of tests performed with equipment compliant with ETSI ES 200 674-1 [i.1] (referred to as HDR-DSRC or CEN-DSRC) and equipment compliant with ETSI EN 302 663 [i.4] operating in the 5 GHz frequency band (referred to as ITS-G5 or ITS-M5). The purposes of the tests are to identify potential interference of ITS-G5 emissions on the HDR-DSRC communications used e.g. for electronic road tolling, and the evaluation of mitigation techniques specified in ETSI TS 102 792 [i.7].

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] ETSI ES 200 674-1 (V2.4.1) (05-2013): "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.2] IEEE 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] ISO 21215: "Intelligent transport systems -- Communications access for land mobiles (CALM) -- M5".

[i.4] ETSI EN 302 663 (V1.2.1) (07-2013): "Intelligent Transport Systems (ITS); Access layer specification for Intelligent Transport Systems operating in the 5 GHz frequency band".

[i.5] ETSI EN 302 665 (V1.1.1) (09-2010): "Intelligent Transport Systems (ITS); Communications Architecture".

[i.6] ISO 21217 (2014): "Intelligent transport systems -- Communications Access for Land Mobiles (CALM) -- Architecture".

[i.7] ETSI TS 102 792 (V1.2.1) (06-2015): "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.8] ETSI TR 102 960 (V1.1.1) (11-2012): "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.9] Commsignia: "OB2-M/ITS-RS2-M User Manual"; version: V1.7.5-b12, 3 (March 2015).

[i.10] Narda Safety Test Solutions: "SRM 3006® Selective Radiation Meter Operating Manual".

[i.11] ETSI EN 300 674-2-1 (V2.1.1) (11-2016): "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.12] ETSI EN 300 674-2-2 (V2.1.1) (11-2016): "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)".

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in ETSI ES 200 674-1 [i.1] and the following apply:

ITS-G5: access technology to be used in frequency bands dedicated for European Intelligent Transport System (ITS)

NOTE: Details of compliance are specified in ETSI EN 302 663 [i.4] and ISO 21215 [i.3].

ITS-M5: communications technology operating in the 5 GHz bands allocated for ITS compliant with IEEE 802.11 [i.2]

NOTE: Details of compliance are specified in ETSI EN 302 663 [i.4] and ISO 21215 [i.3].

3.2 Symbols

For the purposes of the present document, the symbols given in ETSI ES 200 674-1 [i.1] and the following apply:

f_c HDR DSRC downlink centre frequency
$f_{c,ITS}$ ITS-M5 centre frequency
G_{OBU} Gain of the HDR-DSRC OBU antenna in bore-sight direction
G_{RSU} Gain of the HDR-DSRC RSU antenna in bore-sight direction
N_{bundle} Number of HDR-DSRC test signals (ECHO.request) in a test bundle
$N_{success}$ Number of successfully received HDR-DSRC test signals (ECHO.response) in a test bundle
P_{loss} Probability of lost HDR-DSRC test signals
$P_{overlap}$ Probability of an overlap of ITS test signal with interfered HDR-DSRC test signal
$P_{success}$ Probability of successfully received HDR-DSRC test signals
T_{d1} Duration of interfered HDR-DSRC test signal
T_{d2} Duration of interfering ITS test signal
T_{d1d} Duration of HDR-DSRC downlink test signal
T_{d1u} Duration of HDR-DSRC uplink test signal
T_{p1} Repetition period of HDR-DSRC test signal
T_{p2} Repetition period of ITS test signal

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in ETSI ES 200 674-1 [i.1] and the following apply:

AM Amplitude Modulation
CEN European Committee for Standardization
CEPT Conférence Européenne des Administrations des Postes et des Télécommunications
CTI Centre for Testing and Interoperability
DC Direct Current
DSRC Dedicated Short Range Communication
EFC Electronic Fee Collection
EIRP Effective Isotropic Radiated Power
ETC Electronic Toll Collection

FSK	Frequency Shift Keying
HDR	High Data Rate
HDR-DSRC	High Data Rate - DSRC
ISO	International Organization for Standardization
ITS	Intelligent Transport Systems
ITS-SU	ITS Station Unit
ITS-SU	ITS Station Unit
JRC	Joint Research Centre (of the European Commission)
LPDU	Link Protocol Data Unit
MAC	Medium Access Control
MDR-DSRC	Medium Data Rate-DSRC
MIB	Management Information Base
OBU	On Board Unit
OCB	Outside the Context of a BSS
OFDM	Orthogonal Frequency Division Multiplexing
PSK	Phase Shift Keying
RF	Radio Frequency
RSU	Road Side Unit
SRM	Selective Radiation Meter
TTT DSRC	Traffic Transport Telematics DSRC
TTT	Transport and Traffic Telematics
TX	Transmit

4 HDR-DSRC

4.1 Operational characteristics

Typical HDR-DSRC EFC/ETC installations are:

- Free-flow tolling installations with up to about 6 parallel lanes (typical 3 to 4 lanes in each traffic direction).
- Toll plazas with automatic barriers with up to about 40 parallel lanes (typical around 10 to 20 lanes in each traffic direction).

The geometrical coordinate system of HDR-DSRC installations used in the present document is depicted in Figure 1 and Figure 2.

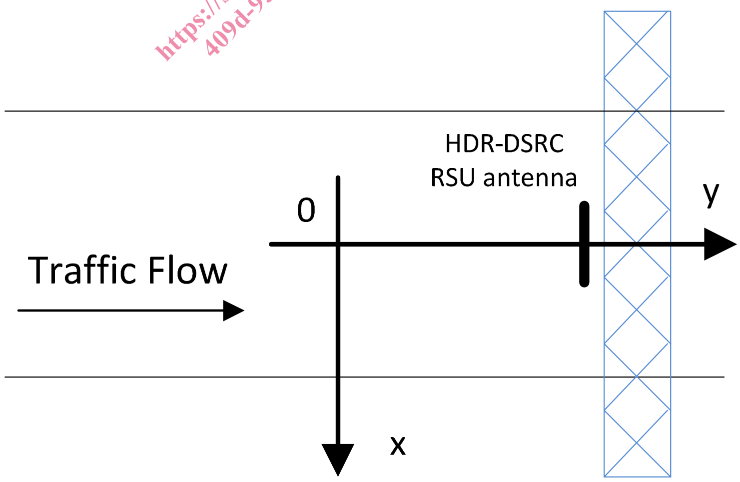

Figure 1: HDR-DSRC installation - top view

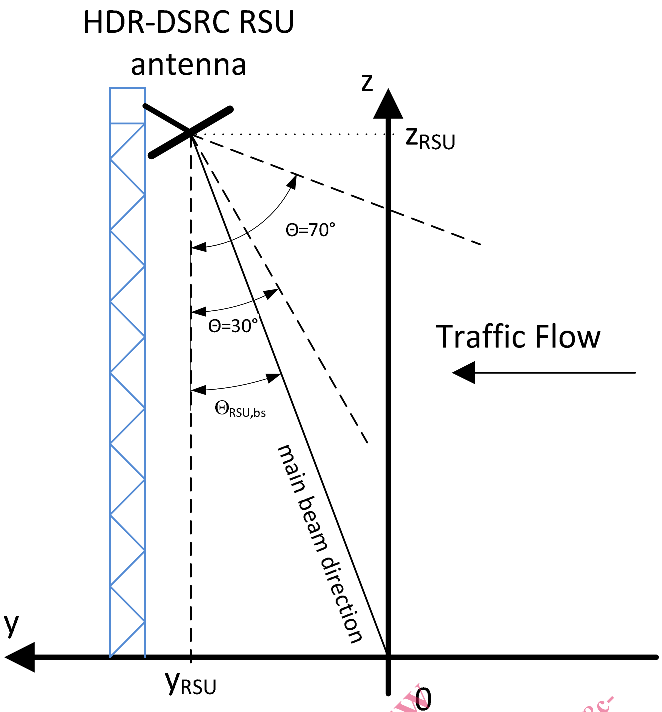

Figure 2: HDR-DSRC installation - side view

The position {x=0, y=0, z=0} is the intersection of the main beam of the HDR-DSRC RSU antenna with the lane. The centre of the HDR-DSRC RSU antenna is at the position {$x=x_{RSU}=0$, $y=y_{RSU}$, $z=z_{RSU}$}.The main beam direction of the HDR-DSRC RSU antenna is given by the angle $\Theta=\Theta_{RSU,bs}$. Limits of radiated power as a function of Θ are presented in Table 1. The position of a HDR-DSRC OBU (not shown in the above figures) is {$x=x_{OBU}$, $y=y_{OBU}$, $z=z_{OBU}$}.

A typical installation of HDR-DSRC RSUs is presented in Figure 3. The angle $\Theta_{RSU,bs}$ is very small and thus the hot spot on the lane is very limited in length (y-axis in Figures 1 and 2).

Figure 3: Typical HDR-DSRC RSU installation

4.2 Technical characteristics

4.2.1 Roadside unit

Characteristics of HDR-DSRC RSUs are presented in Table 1.

Table 1: Parameters of a typical HDR-DSRC RSU

HDR-DSRC RSU RF parameter	Value	Comment
Receiver bandwidth	(0,7 MHz + 0,288 MHz) × 2 = 1,976 MHz	FSK frequency deviation (0,7 MHz) plus symbol rate bandwidth considering the Manchester coding scheme and the uplink symbol rate of 288 kbit/s.
Receiver sensitivity	≤ -92 dBm	
Receiver centre frequency	f_c ± 10,7 MHz	
Antenna bore sight direction, see Figure 2	$\Theta_{RSU,bs}$	Depends on installation.
Antenna polarization	Vertical linear	
Antenna cross polarization	> 20 dB	In boresight.
	≥ 10 dB	-3 dB area.
Transmitter bandwidth	f_c ± 1,842 MHz	Considering the Manchester coding scheme and the symbol rate of 1 842 kbit/s.
Transmitter angular EIRP mask Θ is the angle relative to a vector perpendicular to the road surface, pointing downwards, see Figure 2	≤ +39 dBm	0° ≤ Θ ≤ 30°.
	≤ +33 dBm	30° < Θ ≤ 50°.
	≤ +23 dBm	50° < Θ ≤ 70°.
	≤ +15 dBm	Θ > 70°.
Transmitter carrier centre frequency f_c	5,8 GHz, 5,81 GHz	5,81 GHz is an optional centre frequency potentially used in the future for free-flow tolling.
Downlink modulation scheme	ASK-OOK	
Downlink data coding	Manchester	
Downlink bit rate	921 kbit/s	
Protection criterion (S/I) - co-channel rejection limit	6 dB	FSK, 2-PSK.

4.2.2 Onboard unit

Characteristics of HDR-DSRC OBUs are presented in Table 2.

Table 2: Parameters of a typical HDR-DSRC OBU

HDR-DSRC OBU RF parameter	Value	Comment
Wake-up sensitivity	≤ -40 dBm	Wake-up on a defined pattern.
Receiver sensitivity	≤ -40 dBm	Measured within the 35° border of a cone symmetrically around boresight direction as declared by the manufacturer.
Antenna bore sight direction	not directly specified in [i.1]	Depends on installation in vehicle.
Antenna cross polarization	> 10 dB	In boresight.
	≥ 6 dB	-3 dB area.
Antenna gain outside HDR-DSRC OBU active angle range	≤ G_{OBU} - 1,5 dB	
Antenna polarization	either vertical linear or left-hand circular	
Vehicle windscreen loss	3 dB	Depends on installation in vehicle.
Transmitter bandwidth	f_c ± (10,7 MHz + 0,7 MHz + 0,288 MHz) = f_c ± 11,688 MHz	See uplink modulation scheme, data encoding, and data rate. Same data sent simultaneously in both sidebands.
Transmitter maximum output power level, Single-sideband EIRP	< -14 dBm	Measured at the 35° border of a cone symmetrically around boresight direction, i.e. at the border of the -3 dB area.
Transmitter sub carrier centre frequencies	f_c ± 10,7 MHz	Sub-carrier @ 10,7 MHz FSK modulated with two tones ±0,7 MHz: Binary FSK (±700 kHz) on sub-carrier at 10,7 MHz.
Uplink modulation scheme	AM	On carrier.
Uplink data coding	Manchester	
Uplink bit rate Same data are sent simultaneously in both sidebands	144 kbit/s	

Figure 4 shows a worst case theoretical HDR-DSRC OBU antenna pattern compliant with the definition of the 3 dB area in ETSI ES 200 674-1 [i.1]. The figure is normalized to the antenna gain in bore-sight direction and shows the square-law attenuation as function of the opening angle Θ of the cone in the range zero degree (bore-sight) to 90°.

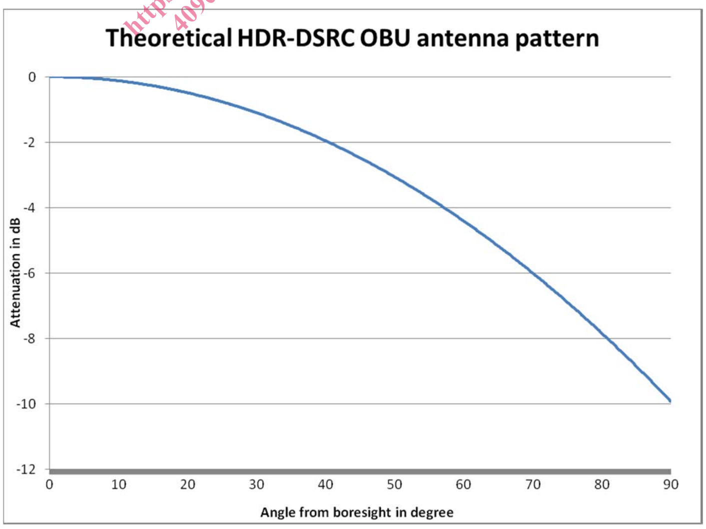

Figure 4: Worst case theoretical HDR-DSRC OBU antenna pattern compliant with ETSI ES 200 674-1 [i.1]