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Technical Report

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

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Foreword

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

1 Scope

European CEN Dedicated Short Range Communication (DSRC) equipment operating in the frequency range from 5 795 MHz to 5 815 MHz can suffer from interference caused by Intelligent Transport System (ITS) transmitters and other users of the same and adjacent frequency bands. The present document provides guidance on how to achieve co-existence between existing DSRC equipment and other users such as ITS equipment.

2 References

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2.1 Normative references

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Not applicable.

2.2 Informative references

The following referenced documents are not essential to the use of the present document but they assist the user with regard to a particular subject area. For non-specific references, the latest version of the referenced document (including any amendments) applies.

[i.1] CEN EN 12253: "Road transport and traffic telematics - Dedicated short-range communication - Physical layer using microwave at 5,8 GHz".

[i.2] CEPT ECC Report 101: "Compatibility studies in the band 5 855 - 5 925 MHz between Intelligent Transport Systems (ITS) and other systems".

[i.3] ETSI EN 302 571: "Intelligent Transport Systems (ITS); Radiocommunications equipment operating in the 5 855 MHz to 5 925 MHz frequency band; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive".

[i.4] CEPT ECC Report 127: "The impact of receiver parameters on spectrum management".

[i.5] ETSI EN 300 674 (all parts): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Road Transport and Traffic Telematics (RTTT); Dedicated Short Range Communication (DSRC) transmission equipment (500 kbit/s / 250 kbit/s) operating in the 5,8 GHz Industrial, Scientific and Medical (ISM) band".

[i.6] ISO 21218:"Intelligent Transport Systems - Communications access for land mobiles (CALM) - Medium Service Access Points".

3 Definitions, symbols and abbreviations

3.1 Definitions

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

adjacent band: part of the radio-frequency spectrum that is close to the DSRC spectrum defined by [i.7] and [i.8]

amplitude envelope: magnitude of the complex analytic representation of the modulated signal.

NOTE: It describes the amplitude variation of a modulated sinusoidal signal as a function of time.

boresight: direction of maximum radiation of a directional antenna

NOTE: If boresight cannot be determined unambiguously, then boresight is declared by the provider.

broadband interferer: noise like interfering signal that covers more than one of the DSRC channels in the frequency domain

carrier frequency: frequency to which the RSU transmitter is tuned

NOTE: In DSRC, the carrier frequency is in the centre of a channel.

channel: continuous part of the radio-frequency spectrum to be used for a specified emission or transmission

NOTE: A radio-frequency channel may be defined by two specified limits, or by its centre frequency and its bandwidth, or any equivalent indication. It is often designated by a sequential number. A radio-frequency channel may be time-shared in order to allow radio communication in both directions by simplex operation. The term "channel" is sometimes used to denote two associated radio-frequency channels, each of which is used for one of two directions of transmission, i.e. in fact a telecommunication circuit.

communication zone: spatial region within which the OBU is situated such that its transmissions are received by the RSU with a bit error ratio of less than a specified value

cross-polar discrimination, ellipticity of polarization: ratio P^{rd}/P^{rd} of power level P^{rd} of the left hand circular polarized wave to the power level P_{RHCP} of the right hand circular wave when the total power of the transmitted wave is $P^{rd} + P^{rd}$

NOTE: Antennas designed to transmit left hand circular waves may transmit some right hand circular waves in addition.

cross polarization: See cross-polar discrimination.

down link: signal transmitted from the RSU to the OBU

equivalent isotropically radiated power: signal power fed into an ideal loss-less antenna radiating equally well in all directions that generates the same power flux at a reference distance as the one generated by a signal fed into the antenna under consideration in a predefined direction within its far field region

narrowband interferer: interfering signal with a bandwidth much smaller than the DSRC sub-channel bandwidth

OBU sleep mode: optional mode for battery powered OBUs that allows to save battery power

NOTE 1: In this mode, the OBU can only detect the presence of a DSRC down-link signal which under certain defined conditions, see CEN EN 12253 [i.1], will lead to wake-up, i.e. a transition to the transmit mode.

NOTE 2: An OBU may be either in sleep mode, the stand-by mode, or the transmit mode.

polarization: locus of the tip of the electrical field strength vector in a plane perpendicular to the transmission vector

power envelope: describes the power variation of a modulated sinusoidal signal as a function of time

RSU active angle: defines a cone where it is allowed to transmit maximum EIRP (parameter D4 in EN 12253 [i.1])

NOTE: Ranges from 0° to $\Theta = 70°$ relative to a vector perpendicular to the road surface pointing downwards (parameter D4a in EN 12253 [i.1]) (see figure 1). The RSU provider may declare a smaller value for Θ.

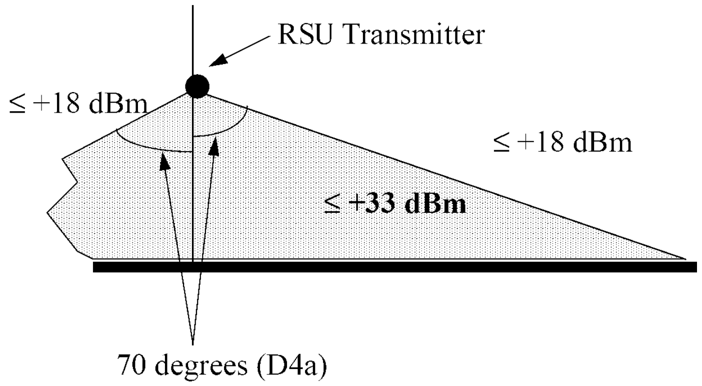

Figure 1: RSU active angle

sub-channel: part of a channel to be used for a specified purpose

NOTE: For DSRC the purpose can be up link or down link.

total peak power level: maximum time domain instantaneous power level defined by the peak voltage $\hat{V}$ at a resistive load R^{rd}

$$\hat{P} = \frac{\hat{V}^2}{R_l} \qquad (1)$$

NOTE: For a sinusoidal signal, the total peak power level is twice the average power level measured with a power meter. For a modulated signal the peak power level is given by the power envelope maximum.

up link: signal transmitted from the OBU to the RSU

3.2 Symbols

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

$\hat{P}$	Instantaneous peak power level
$\hat{V}$	Instantaneous peak Voltage
Θ	Angle relative to a vector perpendicular to the road surface
σ	Standard deviation
a_N	Noise amplitude
Att	Free space attenuation
BER_i	Bit error rate with interference signal
d	Distance between phase centres of transmitting and receiving antenna
f	Frequency
$I3a_{rms}$	Average interference power limit
N_0	Noise power level
p_{AN}	Noise amplitude density
P_d	Discriminator value
P_{emax}	Maximum possible OFDM peak power level
P_{env}	Mean envelope power level (average of RF *peak* power levels)
$p_{env}(t)$	Power envelope

P_{ev}	Power envelope value
P_{LHCP}	Power level of left hand circular polarized wave
p_{ni}	Superposition of noise and interferer amplitude density
$P_{OBUsens}$	OBU sensitivity limit
p_{pe}	Probability of power envelope value
P_{RHCP}	Power level of right hand circular polarized wave
P_{RMS}	Mean RMS power level
R_l	Resistive load

3.3 Abbreviations

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

2-PSK	Binary Phase-Shift Keying
AM	Amplitude Modulation
BER	Bit Error Ratio
C/I	Carrier to Interference Ratio
CEN	Comité Européen de Normalization
DFT	Discrete Fourier Transformation
DL	Down Link
DSRC	Dedicated Short Range Communication
EIRP	Equivalent Isotropically Radiated Power also called e.i.r.p., eirp, E.I.R.P.
EN	European Standard
ERM	Electromagnetic compatibility and Radio spectrum Matters
ETSI	European Telecommunication Standard Institute
IPR	Intellectual Property Rights
ISM	Industrial, Scientific, Medical
ITS	Intelligent Transport System
LHCP	Left Hand Circular Polarized
LP	Linear Polarized
OBU	On Board Unit
OFDM	Orthogonal Frequency-Division Multiplexing
RF	Radio Frequency
RHCP	Right Hand Circular Polarized
RMS	Root Mean Square
RSU	Road Side Unit
RTTT	Road Transport and Traffic Telematics
RX	Receiver
S/I	Signal to Interference Ratio
SNR	Signal to Noise Ratio
TR	Technical Report
TX	Transmitter
UL	Up Link
UWB	Ultra WideBand

EN 12253 [i.1] list of down-link parameter abbreviations:

D1	Carrier frequencies
D4	Maximum EIRP
D4a	Angular EIRP mask
D5	Polarization
D5a	Cross polarization
D8	DL bit rate
D9	DL bit error ratio
U1-0	Sub-carrier frequency 1,5 MHz
U1-1	Sub-carrier frequency 2 MHz
U5	Polarization
U5a	Cross polarization
U8	UL bit rate

4 Summary

4.1 Overview

The following elementary interference scenarios to CEN DSRC by other users of the same and adjacent frequency bands have been identified:

a) Interferer located within RSU active angle at UL frequency.

b) Interferer located outside RSU active angle at UL frequency.

c) Interference to OBU receiver.

d) Disturbance of OBU power save mode.

These interference scenarios are elementary. Most practical cases are represented by one or more of those elementary interference scenarios.

While scenarios a) and b) can be handled by means of frequency regulation - e.g. output power or unwanted emission restrictions for interferers, scenarios c) and d) address also the OBU manufacturers to amend their design to reduce the susceptibility to interference presently caused by the enormous receiver bandwidth as compared with the transmitter signal bandwidth. This aspect is also recognized in ECC Report 127 [i.4].

Since in Europe more than 10 million OBUs are in the market at the time of creation of the present document, such improvements for new OBUs will not have an instantaneous effect. However, these necessary improvements will only reduce the impact of the interference but can not avoid it. Strong interferers will need to implement an additional mitigation technique on their own. Furthermore, it is expected that ITS systems will commence to be placed on the market in 3 to 5 years from the time of creation of the present document.

Annex A of the present documents introduces possible solutions to improve coexistence situations.

4.2 Interference scenarios

Scenarios a) and b) shown in figure 2 apply to interferers that use the UL frequencies shown in figures 7 and 8.

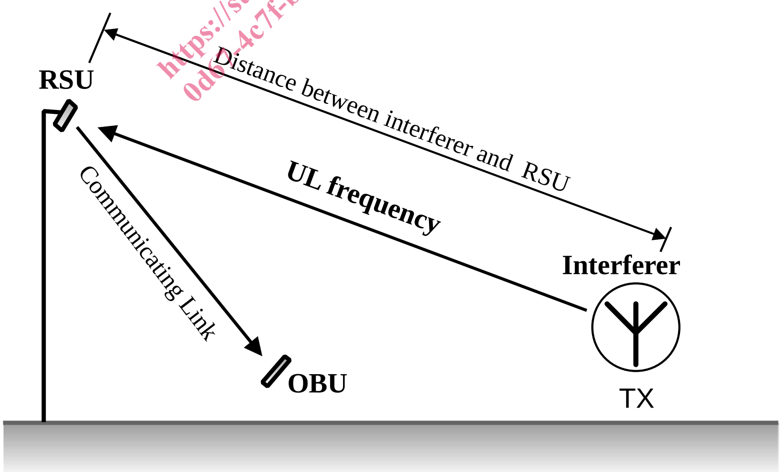

Figure 2: Schematic of interference scenarios a) and b)

From the definition of the active angle of a typical RSU mounted at 5,5 meters height above ground follows that:

Scenario a) applies to interferers within a distance of less than 16 m from this RSU. The interference is typically caused by devices mounted in cars driving through the communication zone.

Scenario b) applies to interferers outside the 16 m range. The interference is typically caused by fixed or mobile interferers located outside the communication zone of the RSU.

Figure 3 shows, under these assumptions, the recommended maximum transmit power spectral density for different polarized interference signals.

The result in figure 3 is in line with the result of ECC report 101 [i.2] which specifies unwanted ITS emission levels of less than -55 dBm/MHz below 5 850 MHz and -65 dBm/MHz below 5 815 MHz. The ITS harmonized European standard EN 302 571 [i.3] includes these limits as a technical requirement.

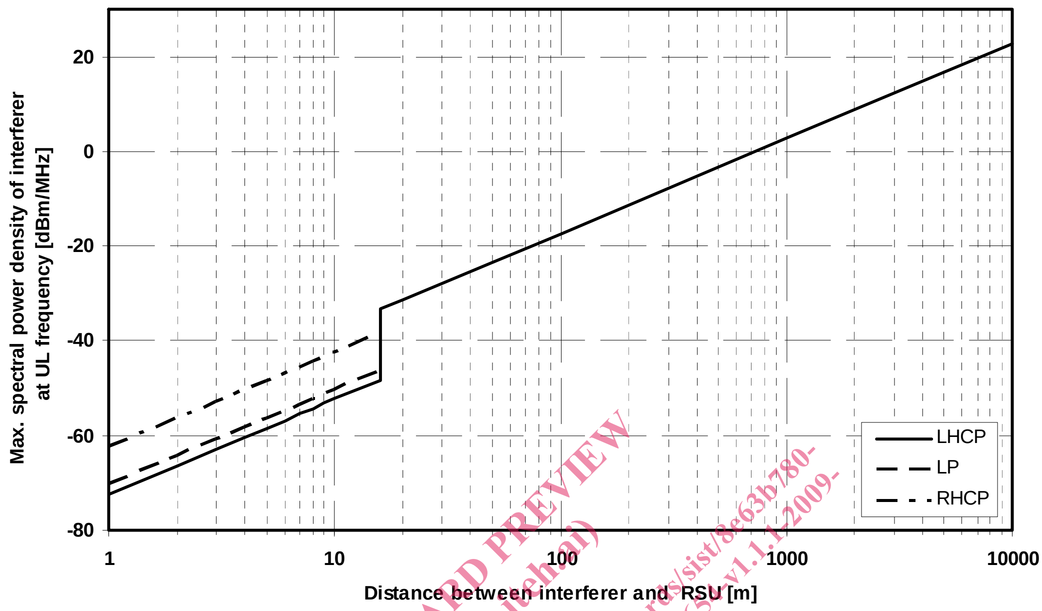

Figure 3: Recommended maximum power spectral density for interference signals

Figure 3 summarizes the results derived from using formulae B.1 and parameters I1b, I1c, I1d, and I2b.

Scenario c) as shown in figure 4 describes data reception interference to OBUs located within the communication zone of an RSU. This interference is caused by fixed or mobile interferers located inside or outside the RSU communication zone.

The RF frontend of the OBU is a broadband design to cope with typical tolling scenarios on highways (multilane free flow), where it is essential that all DSRC channels are processed simultaneously. Therefore the significant parameter that defines an interference limit to this design is the total incident RF peak power level at the OBU (within the DSRC and its adjacent bands). Therefore, a relation between distance to the OBU and total interference peak power level can be defined to protect DSRC.

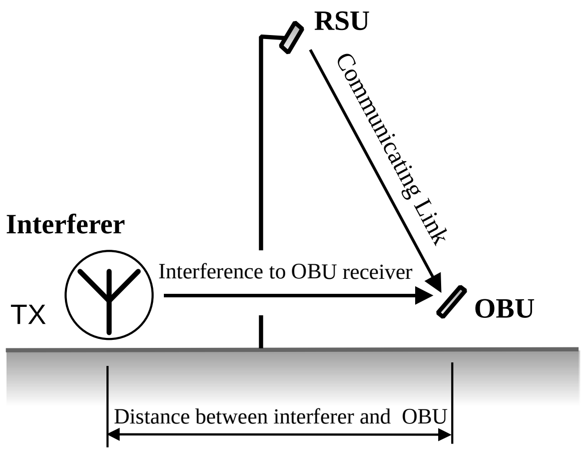

Figure 4: Schematic of interference scenario c)