World Class Standards

CEN DSRC / ITS-G5 coexistence

Basic RF properties

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Signal Properties

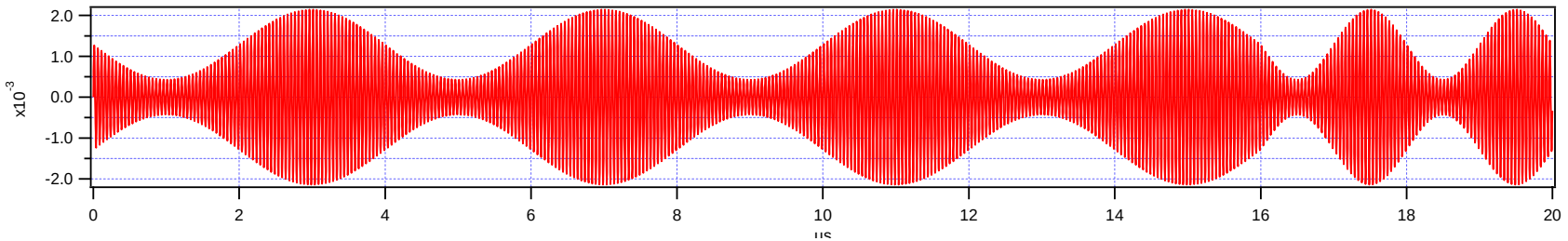
CEN DSRC features

- Used for road tolling and access applications
- Small low price retrofit onboard units (OBU)
- Roadside units (RSU) with defined antenna footprint

CEN DSRC signal properties

RSU

- The RSU is using amplitude shift keying (ASK) with a data rate of 500 kBit/s to modulate the down link (DL) (2 µs per bit).

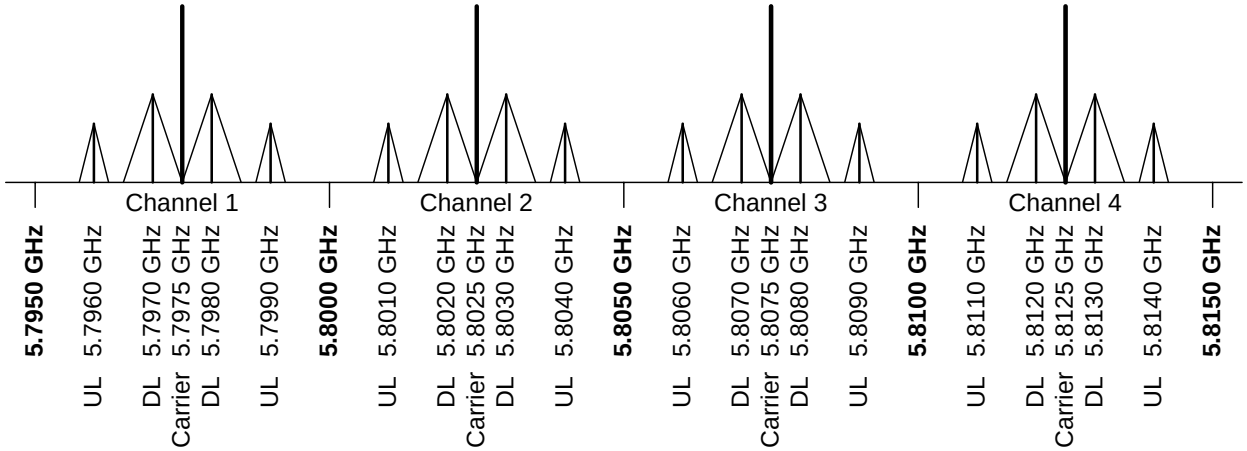


OBU

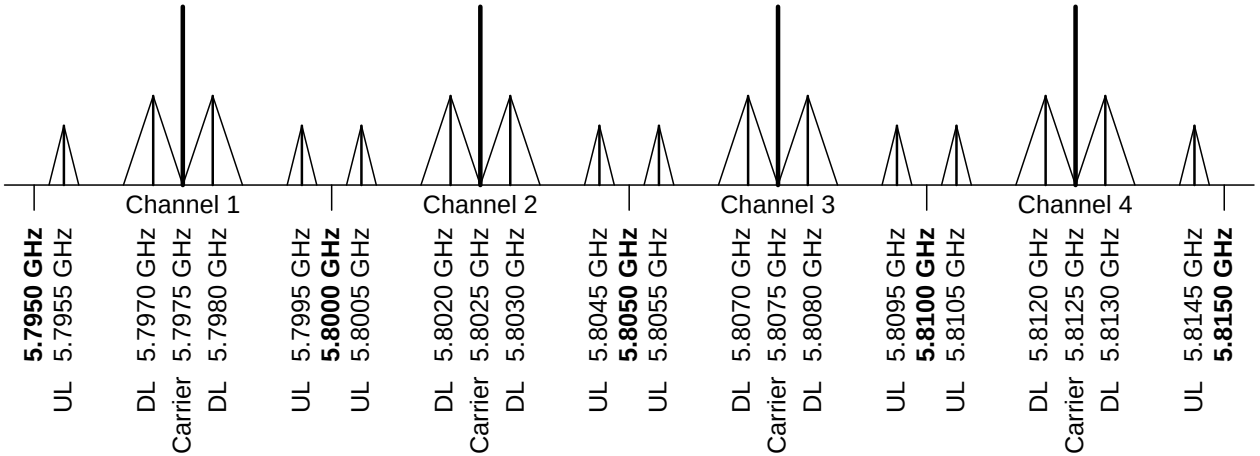
- The OBU acts as a variable reflector to a constant DL (passive back scatter technology).
- By changing the phase of the reflected signal the uplink (UL) is generated. The modulation type of this UL is phase shift keying with two states (2-PSK) and a data rate of 250 kBit/s.
- In addition, either a 1.5 MHz or a 2 MHz sub carrier PSK modulation is used to shift the UL in frequency.

CEN DSRC signal in frequency domain

DSRC frequency utilization for 1,5 MHz sub-carrier frequency (U1-0, CEN EN 12253)

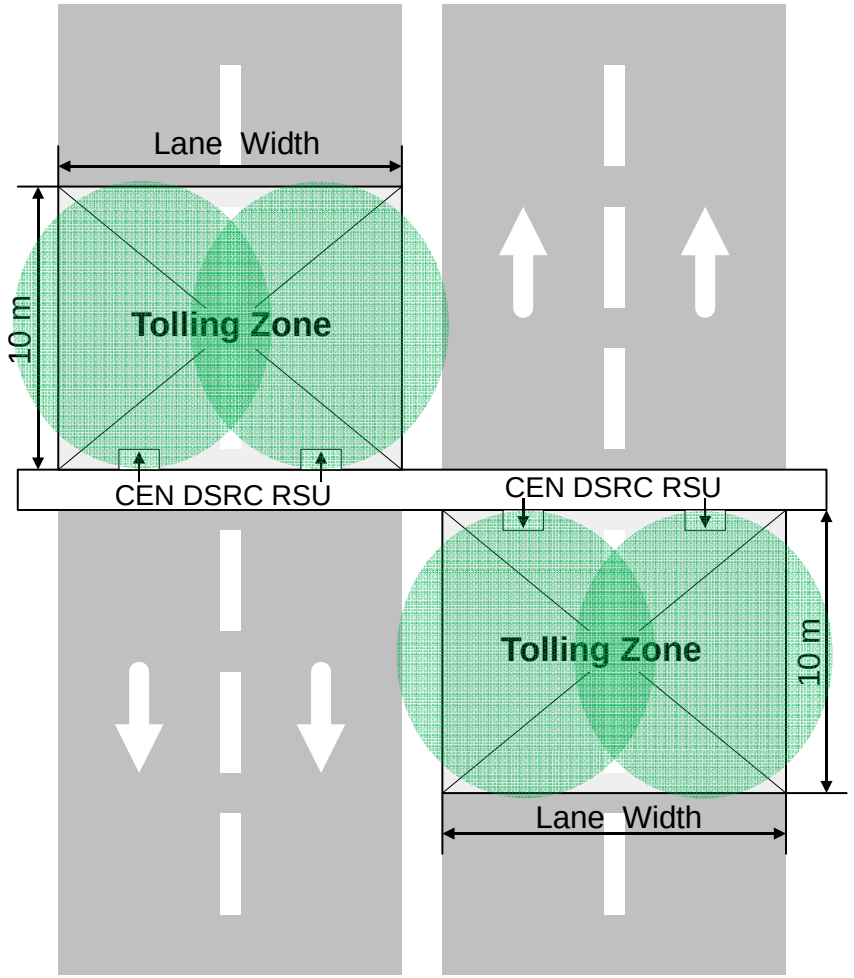


DSRC frequency utilization for 2 MHz sub-carrier frequency (U1-1, CEN EN 12253)



Overlapping of CEN DSRC DL in MLFF

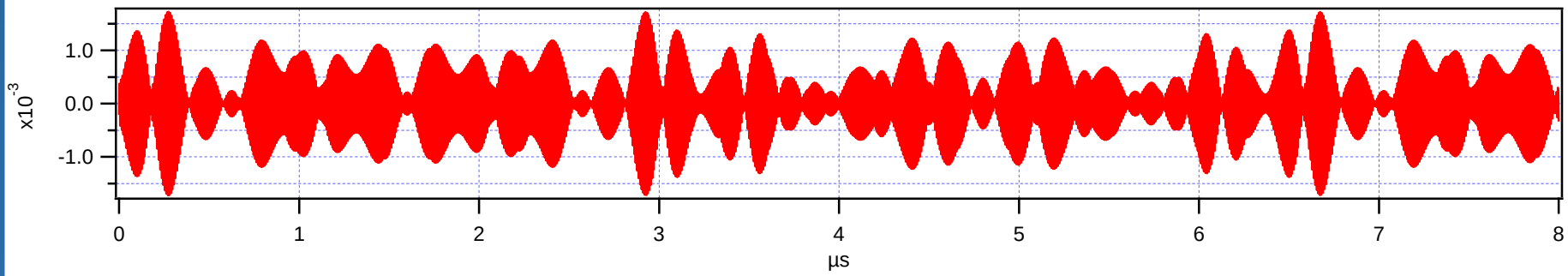
- **Multilane free flow (MLFF)**
  - Several, but not all, MLFF implementations use one RSU per lane with overlapping antenna footprints and synchronised modulation.
  - To avoid signal cancellation in the overlap region, different carrier frequencies are used in adjacent lanes.
  - The OBU uses a broadband envelop detector. Therefore it can demodulate the sum signal of several RSUs.



ITS-G5 signal properties

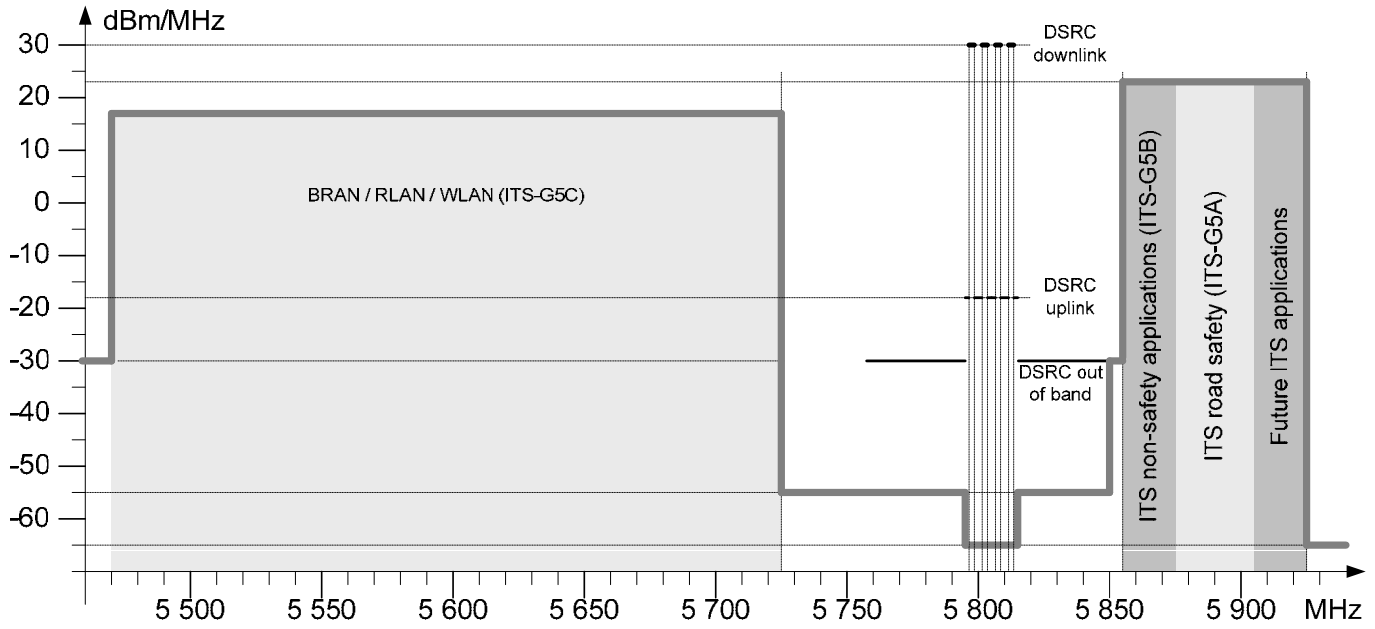
- **All ITS-G5 stations use the physical layer described in IEEE 802.11p which is currently in the progress of being merged with all other IEEE 802.11 standards.**

Signal properties	Value
Channel bandwidth	10 MHz
Carrier spacing	156,25 kHz
Number of used carriers	52 (including 4 pilots) (OFDM)
Symbol duration	8 µs (including 1,6 µs cyclic prefix)
Modulation	2 PSK, 4 PSK, 16 QAM and others



ITS –G5 Signal in frequency domain (from ES 202 663)

Channel type	Centre frequency	IEEE 802.11 CH number	Channel spacing	Default data rate	TX power limit	TX power density limit
G5CC	5 900 MHz	180	10 MHz	6 Mbit/s	33 dBm EIRP	23 dBm/MHz
G5SC2	5 890 MHz	178	10 MHz	12 Mbit/s	23 dBm EIRP	13 dBm/MHz
G5SC1	5 880 MHz	176	10 MHz	6 Mbit/s	33 dBm EIRP	23 dBm/MHz
G5SC3	5 870 MHz	174	10 MHz	6 Mbit/s	23 dBm EIRP	13 dBm/MHz
G5SC4	5 860 MHz	172	10 MHz	6 Mbit/s	0 dBm EIRP	-10 dBm/MHz
G5SC5	As required in EN 302 571 for the band 5 470 MHz to 5 725 MHz		several	dependent on channel spacing	30 dBm EIRP (DFS master)	17 dBm/MHz
					23 dBm EIRP (DFS slave)	10 dBm/MHz
NOTE: With respect to emission limits (power limit / power density limit), the more stringent requirement applies.						



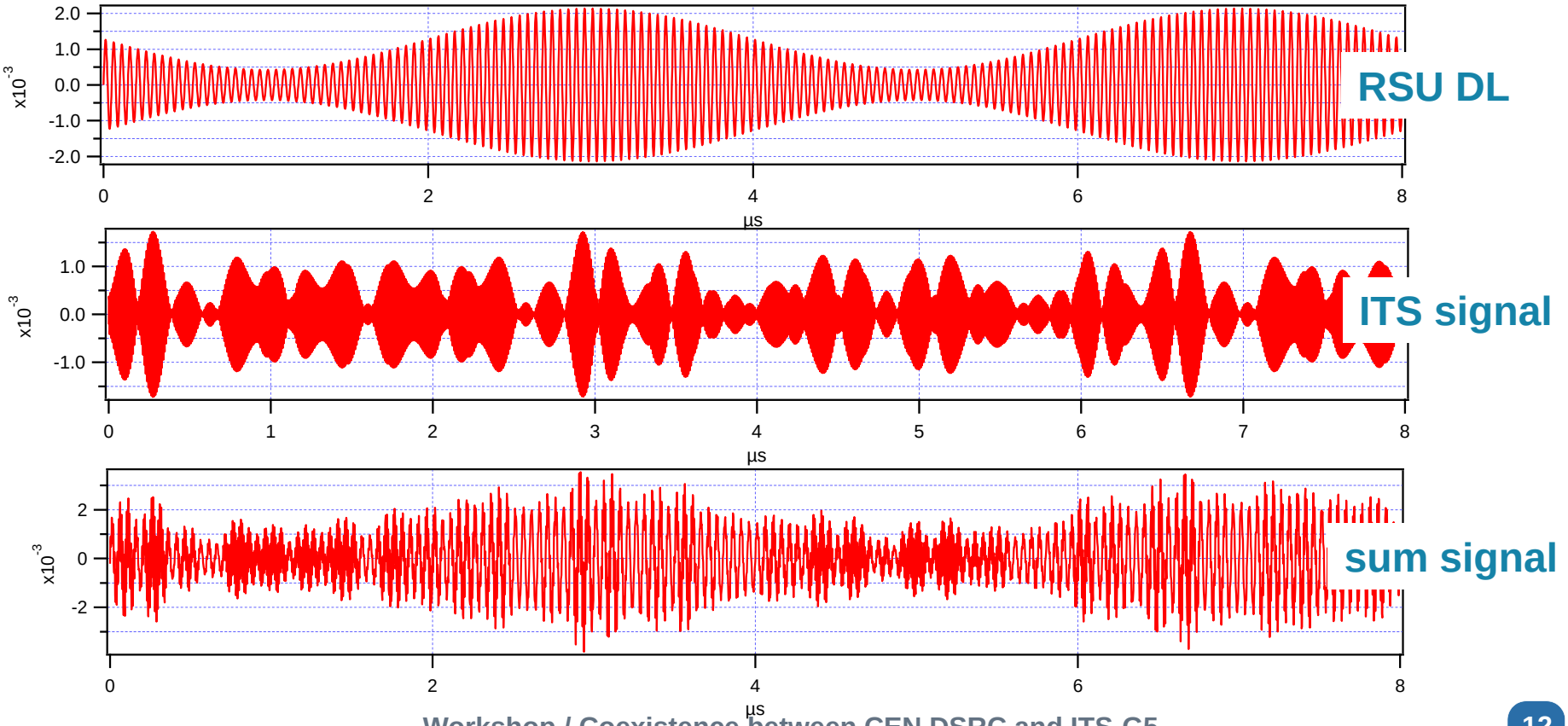
Interference mechanism

Different possible interference scenarios

- ITS-G5 transmitter to CEN DSRC OBU receiver
- ITS-G5 transmitter to CEN DSRC RSU receiver
- CEN DSRC RSU transmitter to ITS-G5 receiver

Interference from ITS-G5 to CEN DSRC OBU

- The CEN DSRC DL and the interfering ITS-G5 signal sum up in the CEN DSRC OBU receiver. Since the OBU uses an envelope detector, the interference signal is treated as additional noise.



Interference from ITS-G5 to CEN DSRC RSU

- **Blocking**
  - The CEN DSRC UL and the interfering ITS-G5 signal sum up in the CEN DSRC RSU receiver.
  - The RSU sensitivity at the antenna for a left hand circular polarised CEN DSRC UL is about -110 dBm to -120 dBm. Therefore the input low noise amplifier or the input mixer can be saturated by a much stronger interference signal even it is not in the CEN DSRC UL frequency band.
  - The interference level that causes this so called blocking, strongly depends on the CEN DSRC implementation.

- **Spurious and unwanted emissions**
  - If the ITS-G5 unwanted emissions in the CEN DSRC UL frequency band exceed -120dBm, interference to the CEN DSRC UL will start to happen.

Interference from CEN DSRC RSU to ITS-G5

- In theory blocking and interference by unwanted emissions of the CEN DSRC RSU can also happen to ITS-G5 stations.

- But...
  - ... since the antenna food print of the CEN DSRC stations is very small, the possible interference area compared to the ITS-G5 communication range will be very small.
  - ... since the input sensitivity of the ITS-G5 station is only in the order of -80 to -90 dBm it will be less sensitive to interference signals compared to CEN DSRC.
  - ... measurements showed no interference from CEN DSRC to ITS-G5.

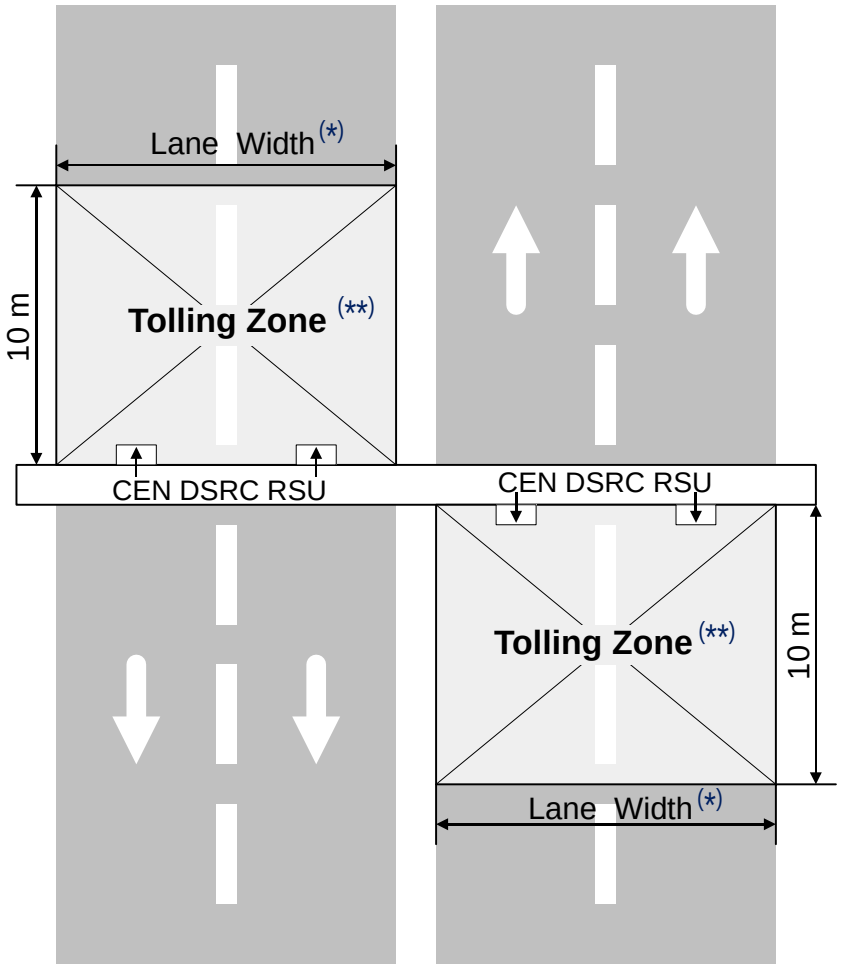
- Interference from the CEN DSRC OBU to an ITS-G5 station has no practical relevance because of the low output power level of the passive backscatter technology used in the OBU.

Coexistence considerations

Power coexistence limits evaluated by STF 395

- **Within a CEN DSRC Tolling Zone the electric field strength of a fixed ITS-G5 station shall not exceed 0,11V/m (-52 dBm).**

- **At the CEN DSRC RSU antenna the field strength of a fixed ITS-G5 station shall not exceed 0,21 V/m (-46 dBm).**



*) The width of the CEN DSRC tolling zone is given by the number of parallel lanes. Usually one RSU is used per lane.

**) Mobile enforcement vehicles will not have a fixed Tolling Zone position or RSU position.

How to achieve coexistence

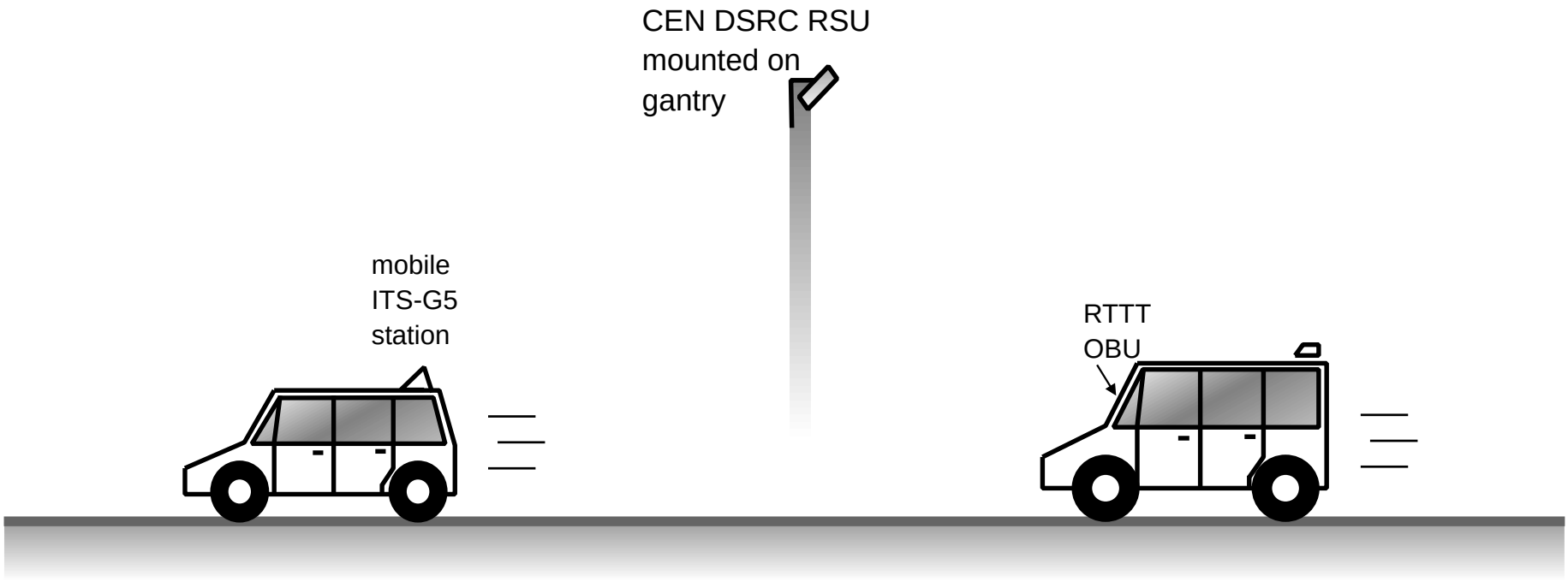
Detect ➢ **Identify the position of the mitigation area**

And

Avoid ➢ **Avoid interference by a set of Coexistence Methods**

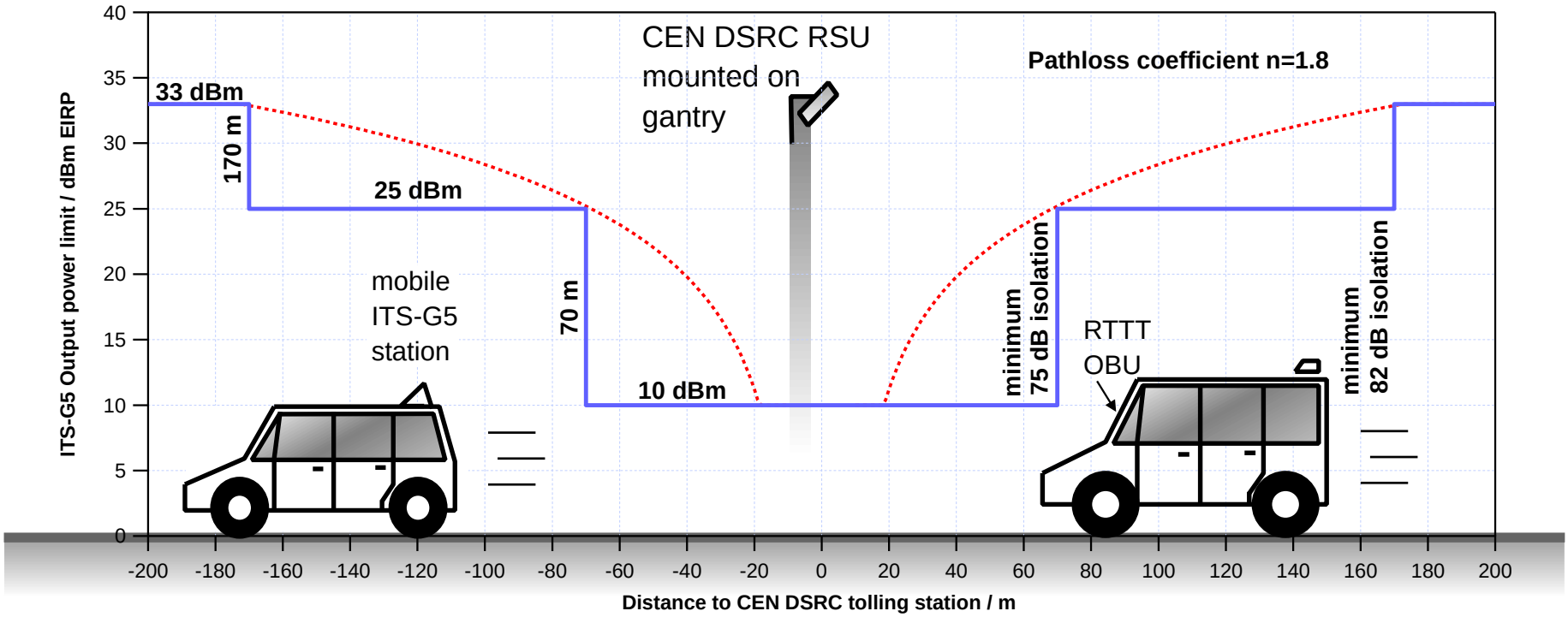
Coexistence Methods

Fixed tolling station



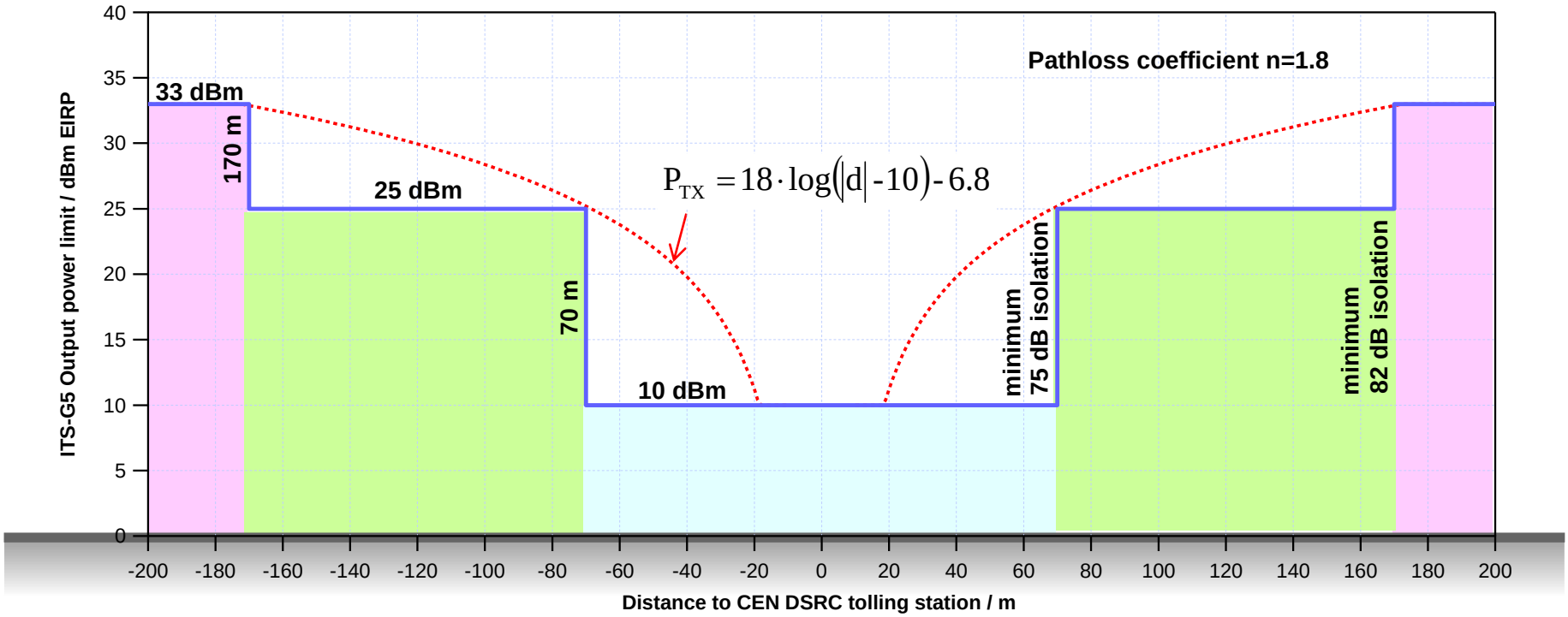
- **Interference can only happen when the CEN DSRC OBU is inside the tolling zone.**

Power coexistence mitigation areas



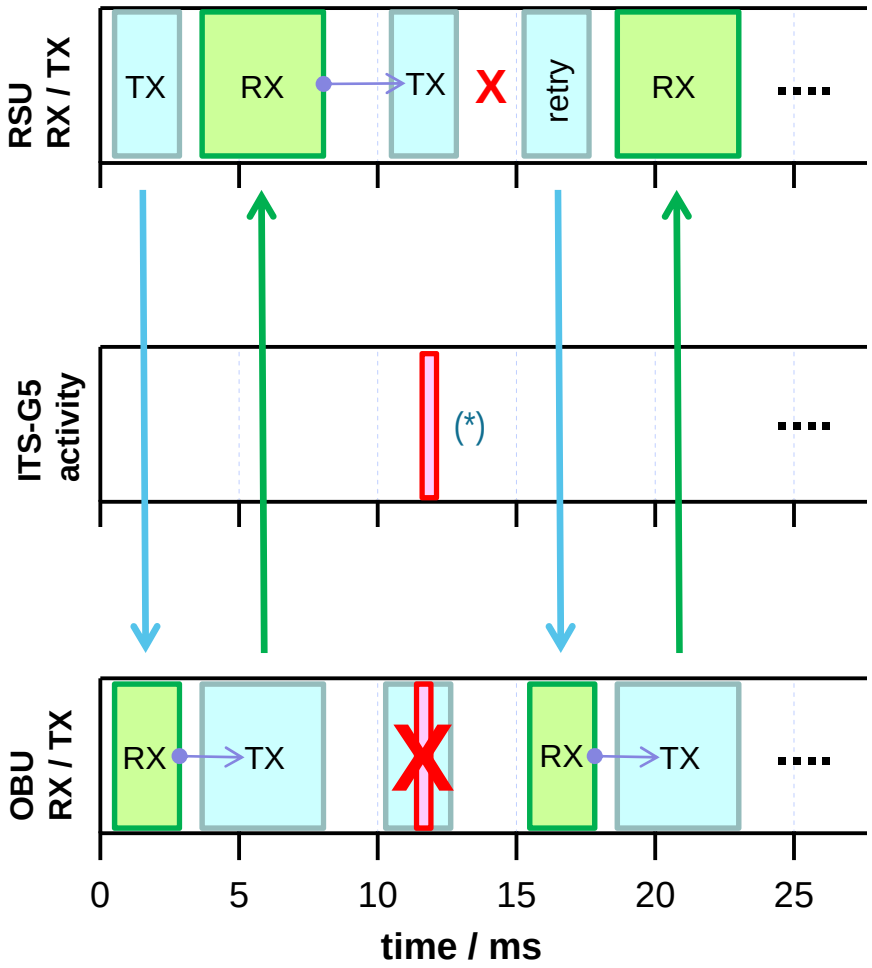
- schematically - not true scale!

Power coexistence mitigation areas



- 10 dBm ITS-G5 output power level assures coexistence (Non interference mode).
- Higher power levels are possible at more than 20 m distance to the tolling station or when a time sharing method is used alternatively.

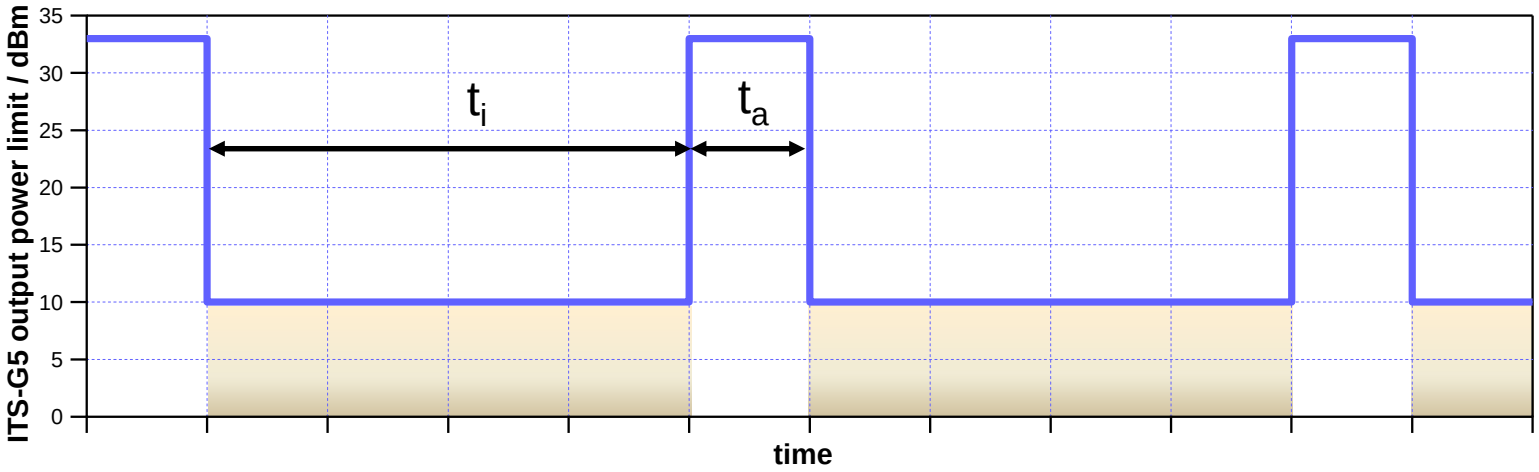
Principles of time sharing coexistence



- Time sharing can work when ITS-G5 is in Low Duty Cycle (LDC) operation.
- Additionally to the channel load, ITS-G5 channel usage timing constraints must be specified.
- STF 411 is dealing with LDC methods.
- STF 420 on ITS-G5 channel configuration could consider this topic.

*) Interference will usually happen in CEN DSRC down link.

Proposed LDC operation

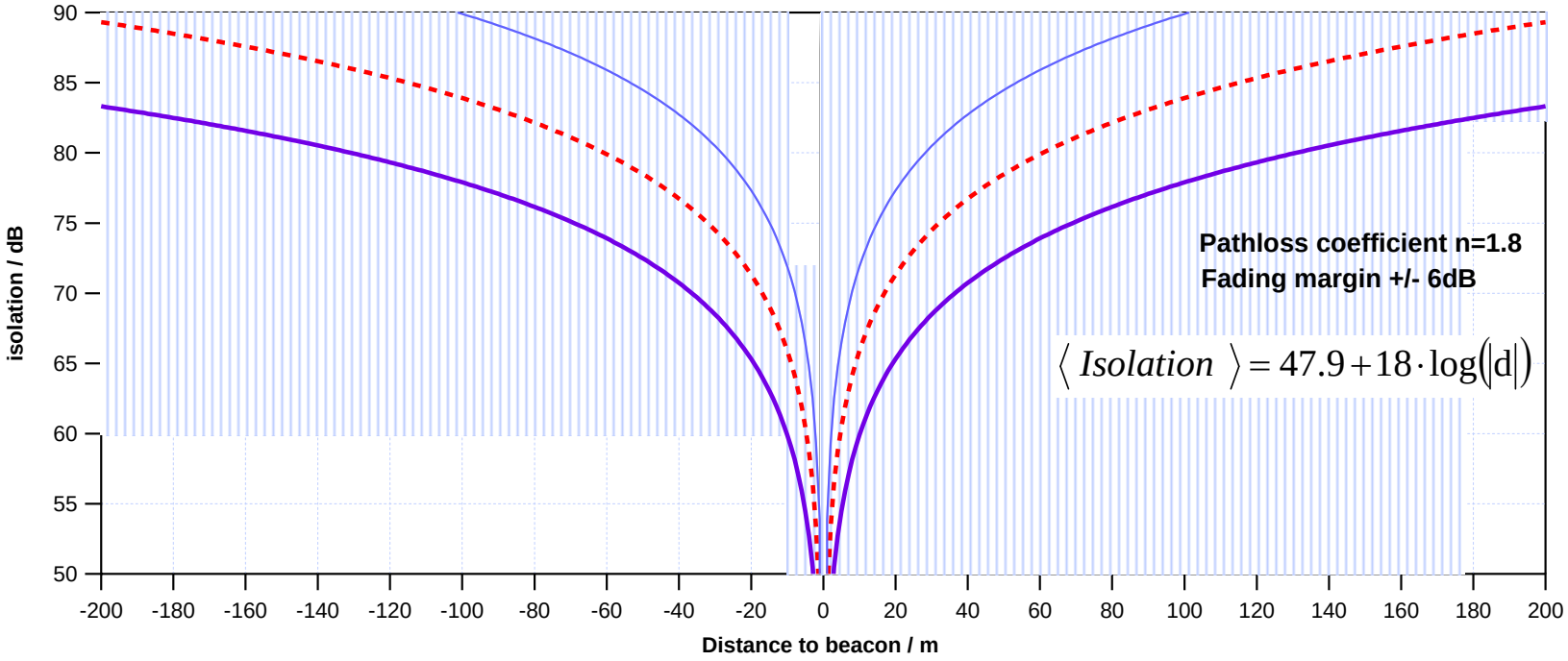


- Additionally to the channel load, the maximum ITS-G5 channel activity time t_a and the minimum idle time t_i should be specified.
- Because of CSMA/CS, an ITS-G5 station monitors the channel continuously. This can be used to determine whether the channel was idle for at least time t_i or active for time t_a. The experiments here at JRC will help to find out whether CSMA/CS sensitivity is sufficient to ensure coexistence.
- During idle time, the channel can still be used with a power level of less than 10 dBm.

Mitigation area identification

Part 1

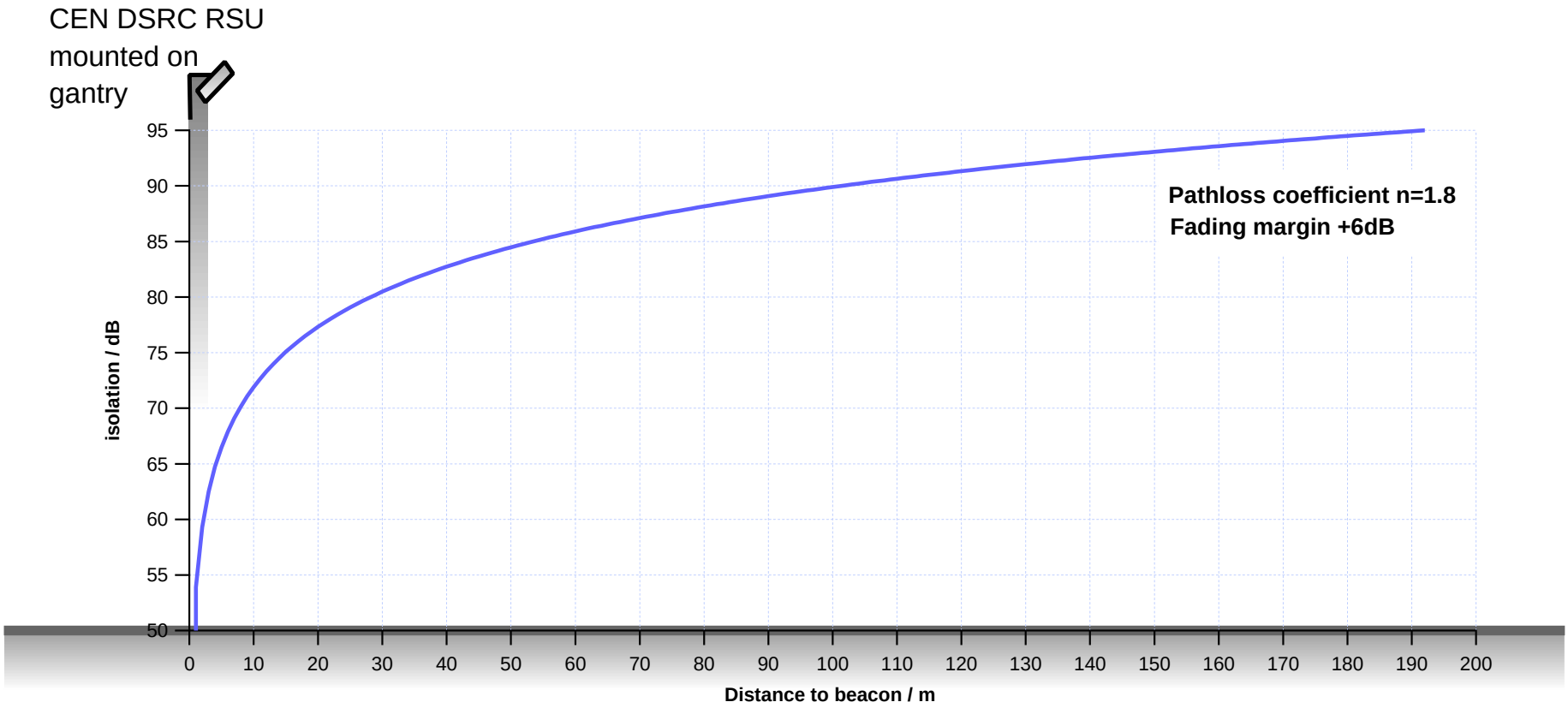
Isolation estimation methods - principle



- Due to fading, the isolation can vary by ±6 dB around its expected value.
- To ensure coexistence, the worst case minimum isolation is essential.
- The use of an RF signal detector can directly estimate this minimum isolation.

Example: CEN DSRC signal detector

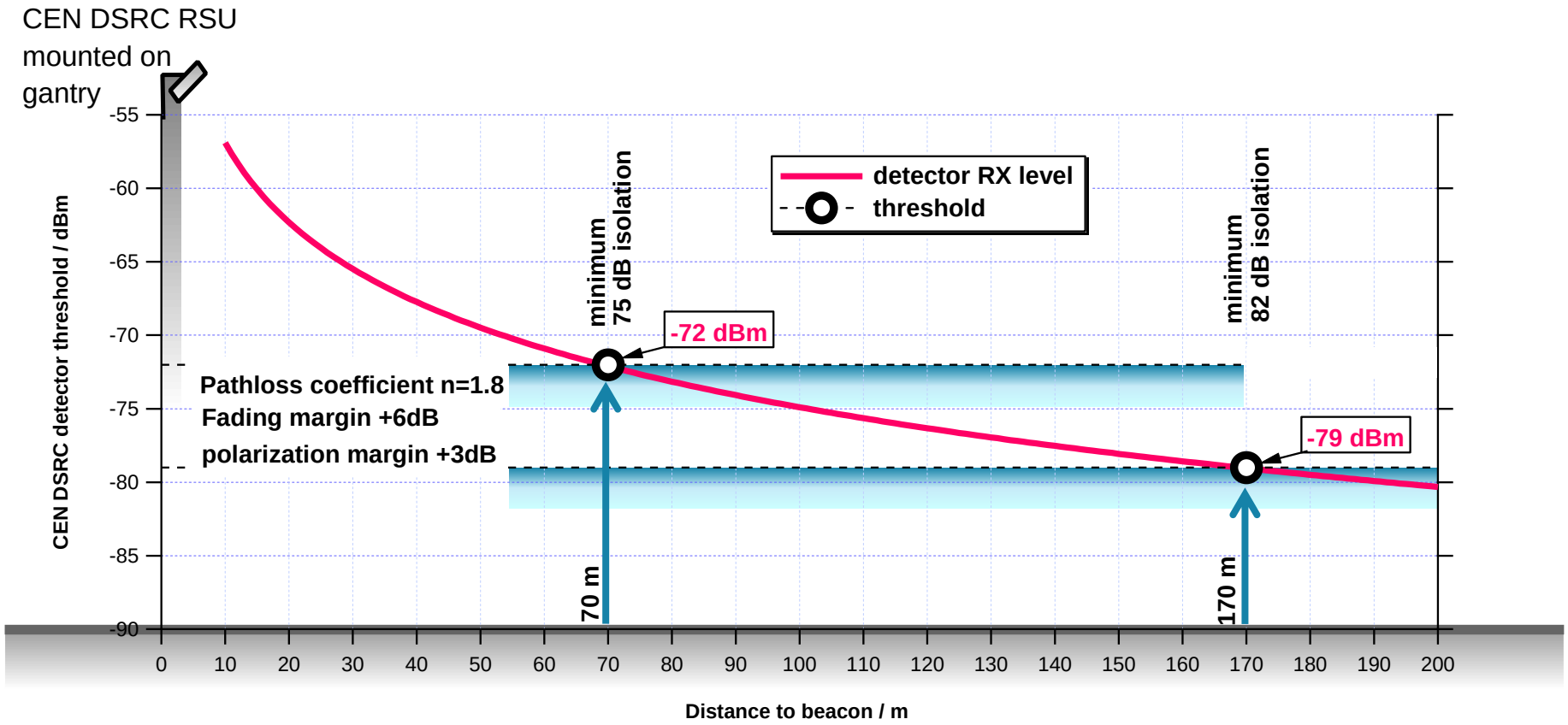
- Expected maximum(*) isolation to a CEN DSRC signal while passing the RSU



*) Because of fading, the isolation between detector and RSU might differ from the isolation to the victim.

Example: CEN DSRC signal detector

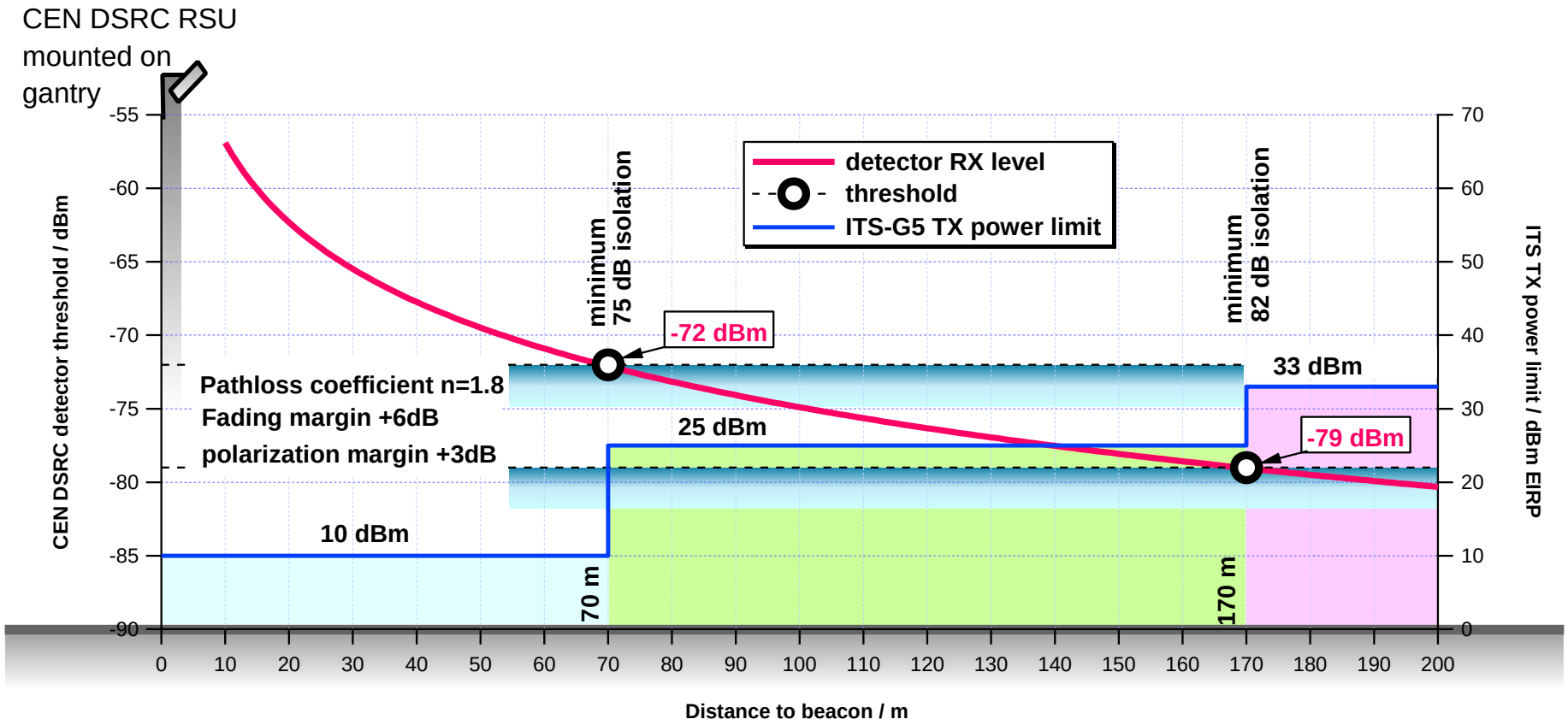
- The TX power level and the antenna characteristics of CEN DSRC are standardised*.



*) Outside the main lobe of the RSU antenna the TX power level is 18 dBm EIRP.

Example: CEN DSRC signal detector

- Example of combination with power coexistence areas (*)



*) As another option LDC could be combined with a CEN DSRC signal detector.

Summary

- Non interference mode with 10 dBm ITS-G5 TX power level
  - no identification of CEN DSRC Toll Station needed
- Non interference mode can also be implemented by use of the proposed LDC operation.
  - no identification of CEN DSRC Toll Station needed
- Combination of power coexistence method and time sharing coexistence (LDC) is possible in one device, but also can coexist from a system view perspective.
- The actual isolation from the victim can be directly estimated by use of an RF detector (no indirect position based estimation).

Thank you for your attention

Abbreviations

CEN	Comité Européen de Normalisation
CSMA/CA	Carrier Sense Multiple Access with Collision Avoidance
CH	Channel
CVIS	Cooperative Vehicle-Infrastructure Systems
DAA	Detect And Avoid
DL	Down Link
DSRC	Dedicated Short Range Communication
EIRP	Equivalent Isotropic Radiated Power
EN	European Norm
ETC	Electronic Toll Collection
ETSI	European Telecommunication Standard Institute
IEEE	Institute of Electrical and Electronics Engineers
ITS	Intelligent Transport System
ITS-G5	acronym for the 5,9 GHz vehicular adhoc network PHY
LDC	Low Duty Cycle
LHCP	Left Hand Circular Polarized
MLFF	Multi Lane Free Flow
OBU	OnBoard Unit
OFDM	Orthogonal Frequency Division Multiplex
PHY	PHYsical (OSI layer)
RF	Radio Frequency
RSU	RoadSide Unit
RX	Receive
TS	Technical Specification
TX	Transmit
UL	UpLink