Automotive

WEBINAR

NEW DEVELOPMENTS IN CISPR AUTOMOTIVE EMI STANDARDS FOR ELECTRIC VEHICLES

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ROHDE&SCHWARZ

Make ideas real

EMC STANDARDS FOR AUTOMOTIVE

EMC Standards for Vehicles and ESA (Electronic Sub Assemblies)

Vehicle Manufacturer	Global	USA	Europe	China	Japan
GS, MB, TL, GMW, B21, etc.	ISO, **CISPR**	SAE	UN ECE Regulation No. 10	GB	JASO

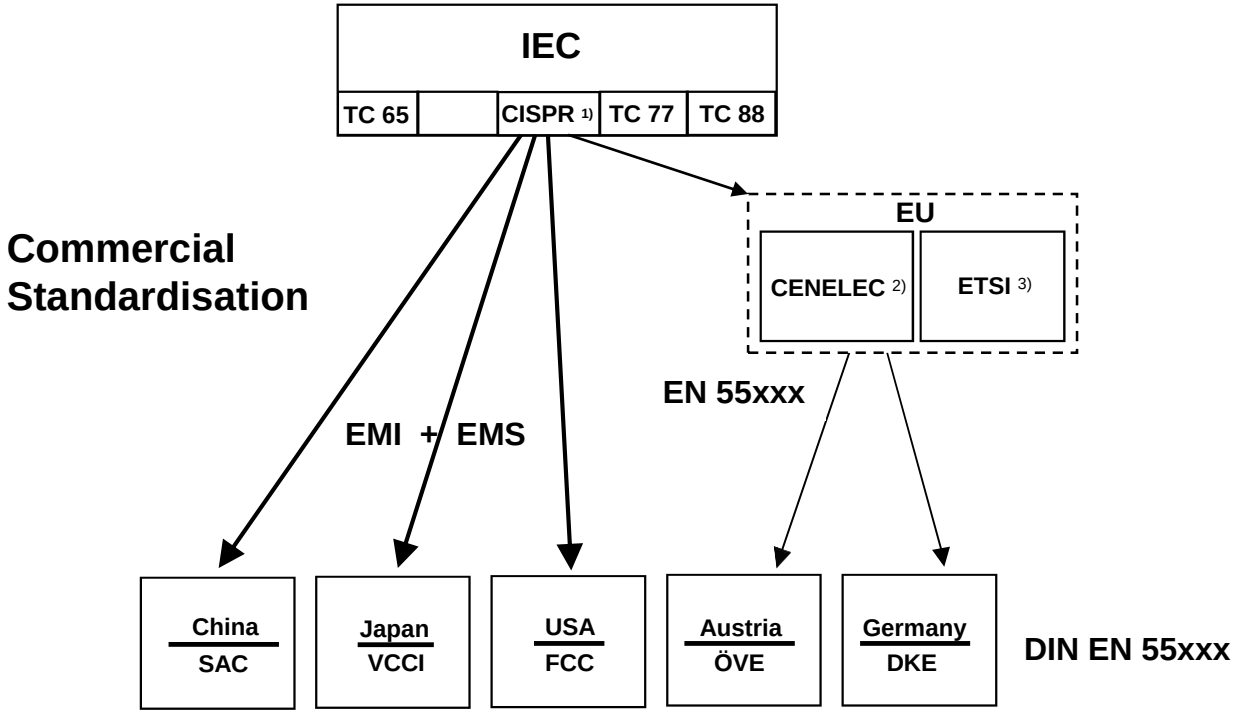
CISPR – PURPOSE

- **CISPR = International Special Committee on Radio Interference [1)]**
  - **Technical committee within the International Electrotechnical Commission (IEC)**
  - **The committee is constituted of 7 sub-committees that fulfil both product (vertical) and basic (horizontal) standardisation roles**
  - **CISPR was established in 1933 and had its first meeting in June 1934 in Paris, with representatives of 6 national committees of the IEC (Belgium, The Netherlands, Luxembourg, France, Germany and UK)**
  - **Today CISPR is one of 109 technical committees of the IEC**
  - **Members of CISPR are 41 National Committees (23 participate/18 observer), EBU, ETSI, CIGRE, IARU and both ITU-R and ITU-T**
- **CISPR was established to consider the protection of radio reception from interference**

Source: Franklin Delano Roosevelt Memorial, Washington DC

1) “Comité International Spécial des Perturbations Radioélectriques”

CISPR – PURPOSE



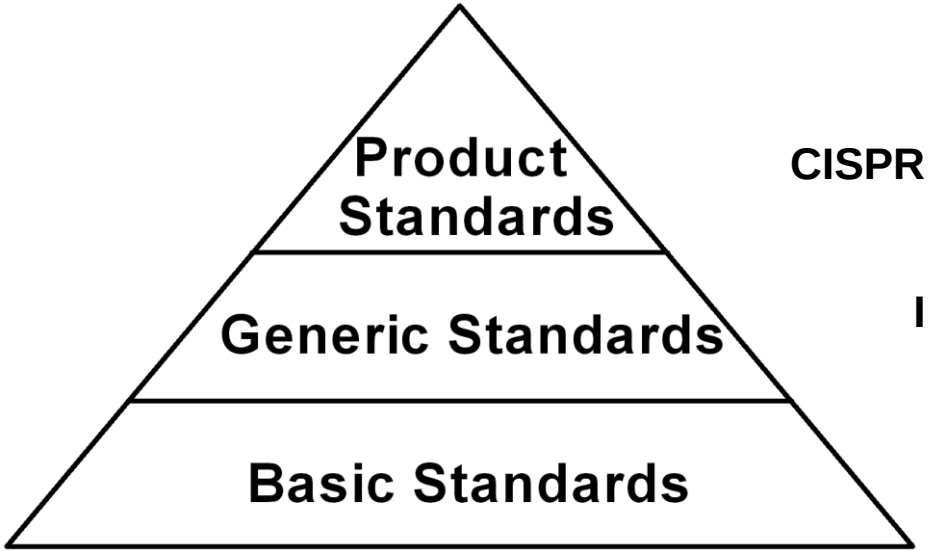
1) CISPR = Comité International Spécial des Perturbations Radioélectriques (Internationales Sonderkomitee für Hochfrequenzstörungen)
2) CENELEC = Comité Européen de Normalisation Electrotechnique (Europäisches Komitee für elektrotechnische Normung)
3) ETSI = European Telecommunications Standards Institute

CISPR – PUBLICATION LEVELS

- **Basic Standards: Developed by CISPR sub-committee A**
  - **The CISPR 16 series is composed of 17 parts**
  - **Defines the measurement apparatus, measurement methods, measurement uncertainty and test facilities**
- **Generic Standards: Developed by CISPR sub-committee H**
  - **IEC 61000-6 series for both emission and immunity testing**
    → IEC 61000-6-3 Residential, commercial and light-industrial environments
    → IEC 61000-6-4 Industrial environments
    → New: IEC 61000-6-8 for commercial and light-industrial
  - **Sets limits through an interference model**
- **Product Standards: Developed by CISPR sub-committees B, D, F, I**
  - **Product and product-family standards for both emission and immunity testing**
  - **Provides both product-specific requirements, such as operation and arrangement of the EUT, measurement methods and measurement uncertainty**

CISPR – PUBLICATION LEVELS

- **CISPR publications are structured into 3 levels**
- **Basic standards come into force with normative references in generic and product standards**



CISPR 11, 12, 14-1, 15, 25, 32 and 36

IEC 61000-6-3, -6-4 , -6-8

CISPR 16 series

AUTOMOTIVE EMI

- CISPR 12
  - Off-board protection
- CISPR 25
  - On-board protection
- CISPR 36
  - Off-board protection electric and electric hybrid vehicles

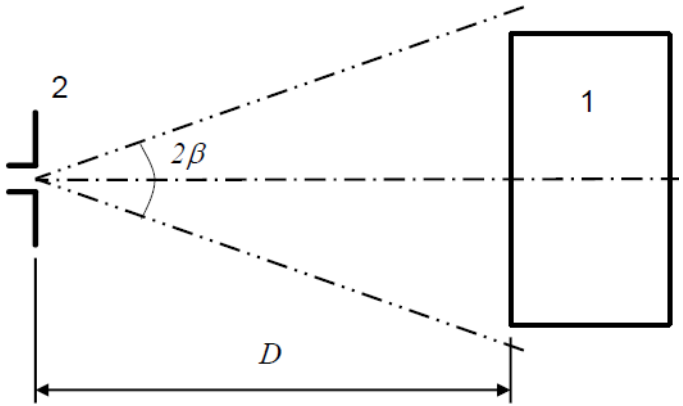
CISPR 12 – PROTECTION OF OFF-BOARD RECEIVERS

Developed by CISPR sub-committee D

- Vehicles, boats and devices with internal combustion engines
- Protection distance 10 m
- Radiated emission **30 MHz to 1000 MHz**
- Used for regulatory purposes
  (referenced in legally binding UN ECE R10)
- Used for CE certification for devices
  chainsaws, water pumps, snow blowers, air compressors, …
- **CISPR 12 Ed. 6** was published in May 2007
- Amendment 1 to CISPR 12:2007 was published in January 2009
  adds Industrial floor cleaning machines

CISPR 12 – PROTECTION OF OFF-BOARD RECEIVERS

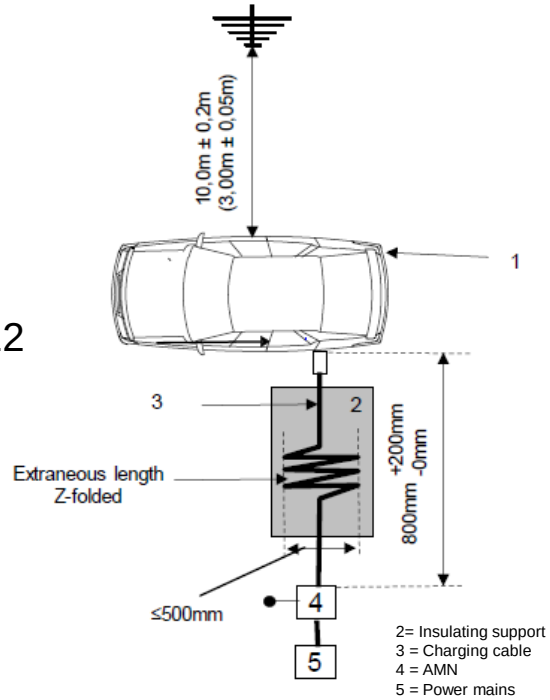
- **What's Coming in Edition 7?**
  - **The references to CISPR 16 will be updated to make FFT-based receivers like R&S®ESW, ESR and ESU applicable for EMI compliance measurements**
  - **The appropriate average detector is the CISPR-AV detector with meter time constant, the alternative use of the pure linear AV detector will be deleted**
  - **Antenna position for vehicles, it is proposed to define the center position of the EUT as reference point if 3 dB antenna beam width covers the entire EUT**



Source: CIS/D/467/CD

CISPR 12 – PROTECTION OF OFF-BOARD RECEIVERS

- **What's Coming in Edition 7? (continued)**
  - **Measurements in charging mode of electric and electric hybrid vehicles if the charger is part of the vehicle**
    - Conducted emission **not** in CISPR 12, (e.g. on-board chargers in IEC 61851-21-1)
    - Radiated emission 30 MHz to 1000 MHz acc. to CISPR 12
    - The measurements shall be performed in engine off mode and all other equipment shall be switched off
    - AC Power mains lines through a **50 µH//50 Ω AMN (R&S®ENV216/432/4200)**
    - DC Power mains through a **5 µH//50 Ω DC-charging-AN**



Source: CIS/D/467/CD

CISPR 12 – PROTECTION OF OFF-BOARD RECEIVERS

- **What's Coming in Edition 7? (continued)**
  - **Measurements in "engine running" mode of electric and hybrid vehicles**
    → Constant speed 40 km/h ± 20 % driven on a dynamometer without load
    → or maximum if top speed of vehicle is less than 40 km/h
    → But speed and load may have significant influence on the emission result
  - **New normative Annex F will be added on the consideration of measurement instrumentation uncertainty (MIU), uncertainty budget (sample calculation) is given in informative Annex G**
  - **Edition 7 failed in final voting stage, Revised committee draft in 2021, Publication expected in 2022**

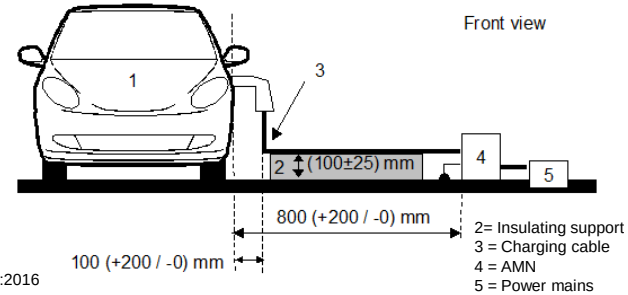
CISPR 25 – PROTECTION OF ON-BOARD RECEIVERS

- **Developed by CISPR sub-committee D**
  - **4th Edition was published on 27 October 2016 and Corrigendum COR1:2017**
  - **In Europe published on national level only, e.g. BS EN 55025:2017 (UK), DIN EN 55025:2018 (Germany)**
  - **EN 55025 is not listed in the Official Journal of the EU and has no legal status**

Therefore, the car component manufacturer has to apply the specific company standards of the car manufacturer, which are usually based on CISPR 25 or EN 55025 respectively

CISPR 25 – PROTECTION OF ON-BOARD RECEIVERS

- **What's New in Edition 4?**
  - **The reference to CISPR 16-1-1 was updated to make FFT-based receivers like the R&S®ESW, R&S®ESR and R&S®ESU applicable for EMI compliance measurements**
  - **The appropriate average detector is the CISPR-AV detector with meter time constant, the alternative use of the pure linear AV detector was deleted**
  - **Frequency range was not extended, maximum = 2.5 GHz**
  - **Dielectric material is not used any more between cable harness and table in the component measurement setup for alternators and generators (Figure 8)**
  - **Disturbance measurements in charging mode of electric and hybrid vehicles if the charger is part of the vehicle**
    - Vehicle test – Voltage at internal antenna
    - The measurements are made without the engine running and all other equipment shall be switched off
    - AMN/AN-HV same as for CISPR 12



Source: CISPR 25:2016

CISPR 25 – PROTECTION OF ON-BOARD RECEIVERS

- **What's New in Edition 4? (continued)**
  - **Apply correction factor for the AN, it is available from the manufacturer of the AN and can easily added as transducer factor in the receiver or system software**
  - **A new informative Annex on chamber validation was added, it contains two alternative validation methods ("long wire" and "reference site method")**
  - **Disturbance measurements on the high voltage (HV) propulsion system of electric vehicles**
    - Disturbance voltage and current, voltage measurement requires specific 5 µH//50 Ω HV-AN, i.e. in shielded box, adaption for shielded cables and additional resistor for discharging to <50 V within 60 s
    - RE for components, ALSE method (150 kHz to 2500 MHz)
    - Coupling between HV and LV system by direct S-parameter measurements (decoupling factor) or based on existing CISPR 25 test set-up (voltage, current and electric field)

CISPR 25 – PROTECTION OF ON-BOARD RECEIVERS

- **What's New in Edition 4? (continued)**
  - **Using the minimum dwell time as defined in Table 2 with a measuring receiver can result in enormous measurement result errors**
  - **In a worst case the receiver will not capture the disturbance signal at all if the dwell time is shorter than the pulse repetition interval of the disturbance signal**
  - **Not suitable for measuring intermittent narrowband signals with CISPR-AV detector! Should be at least:**
    - **160 ms in AM Band (<30 MHz)**
    - **100 ms in Bands >30 MHz**

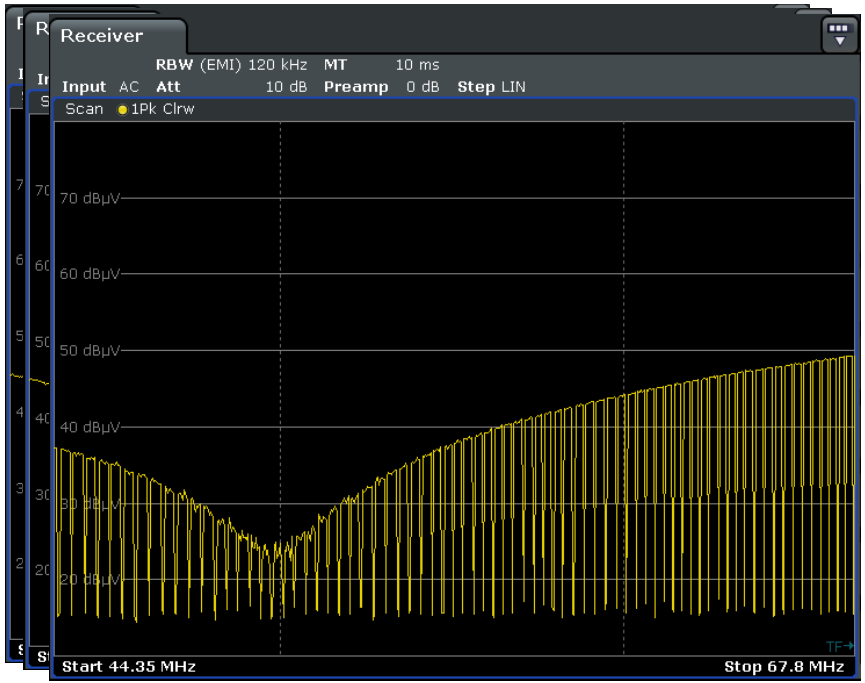
Table 2 – Scanning receiver parameters

Service / Frequency range MHz		Peak detection			Quasi-peak detection			Average detection		
		BW at -6 dB	Step size	Dwell time	BW at -6 dB	Step size	Dwell time	BW at -6 dB	Step size	Dwell time
AM broadcast and mobile services	0,15 - 30	9 kHz	5 kHz	50 ms	9 kHz	5 kHz	1 s	9 kHz	5 kHz	50 ms
FM broadcast	76 - 108	120 kHz	50 kHz	5 ms	120 kHz	50 kHz	1 s	120 kHz	50 kHz	5 ms
Mobile services	30 to 1 000									
TV Band I	41 – 88									
TV Band III	174 – 230									
TV Band IV/V	470 – 890									
DAB	171 - 245									
DTTV	470 - 770	120 kHz	50 kHz	5 ms	Does not apply	Does not apply	Does not apply	120 kHz	50 kHz	5 ms
Mobile service	1 000 - 2 500	120 kHz	50 kHz	5 ms	Does not apply	Does not apply	Does not apply	120 kHz	50 kHz	5 ms
GPS L1 civil	1 567 – 1 583	Does not apply	Does not apply	Does not apply	Does not apply	Does not apply	Does not apply	9 kHz	5 kHz	5 ms

NOTE For emissions generated by brush commutator motors without an electronic control unit, the maximum step size may be increased up to 5 times the bandwidth.

CISPR 25 – PROTECTION OF ON-BOARD RECEIVERS

- **Wrong measurement time can result in enormous errors!**
  - **Pulse modulated carrier with 12 ms pulse period, Time Domain Scan shows closed trace with 12 ms measurement time**
  - **Gaps in TD Scan trace with 10 ms measurement time**
  - **Even when 10 ms yields a closed trace in Stepped Scan, zooming in reveals gaps in the trace**
  - **Important Measurement time ≥ signal period!**

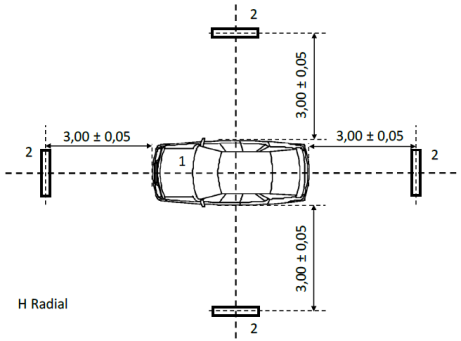


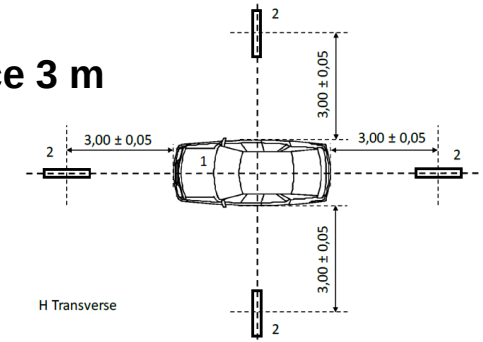
CISPR 25 – PROTECTION OF ON-BOARD RECEIVERS

- **What's Coming in Edition 5?**
  - **Maximum frequency will be extended beyond 2500 MHz for both component (ALSE method) and vehicle (voltage at internal antenna) testing, this will add new frequency bands up to 6 GHz:**
    - 4G: 2496 to 2690 MHz, 3300 to 3800 MHz and 5150 to 5925 MHz
    - WiFi: 5150 to 5350 MHz and 5470 to 5725 MHz
    - C2X (Car-to-X Communication): 5850 to 5925 MHz
  - **Adds new GNSS band: BDS (BeiDou System)**
  - **Revision of measurement methods in charging mode of electric and hybrid vehicles based on charging mode concept in IEC 61851-1 (Mode 1 to 4)**
  - **New Annexes will be added on the consideration of measurement instrumentation uncertainty (MIU), also uncertainty budget is given (sample calculation)**

CISPR 36 – PROTECTION OF OFF-BOARD RECEIVERS

- **Developed by CISPR sub-committee D**
  - **Edition 1 was published on 22 July 2020**
  - **Electric and hybrid electric road vehicles**
  - **Quasi-peak limits for radiated emission (magnetic field) 150 kHz to 30 MHz, similar to CISPR 11 Class B Group 2 but more stringent above 4 MHz**
  - **Measurement with 60 cm Loop Antenna like R&S®HFH2-Z2E in Radial (X) and Transverse (Y) direction at four positions, centre of loop at fixed height of 1,30 m, measurement distance 3 m**
  - **Measurements with electric engine running only, constant speed 40 km/h ± 20 % driven on dynamometer without load**
  - **New normative Annex A on MIU, sample calculation in informative Annex B**





Source: CISPR/D/462/CDV)


Automotive
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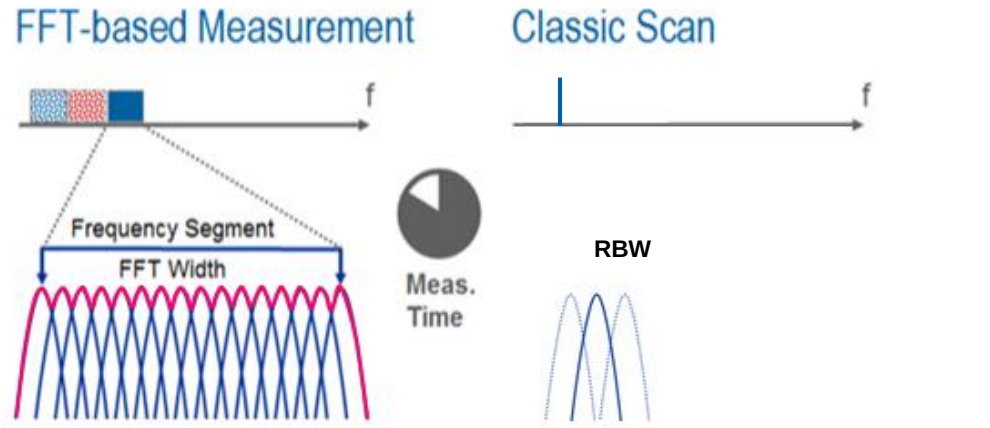
APPENDIX

CISPR 16 – FFT-BASED MEASURING RECEIVERS

Motivation for FFT-based measurement instrumentation

- **More Speed – FFT-based receivers are measuring spectral segments much wider than the resolution bandwidth during the measurement time by parallel calculation at several frequencies**
- **More Reliable – FFT allows application of longer measurement times, e.g. for measuring intermittent signals**
- **More Insight – FFT makes enhanced measurement functions like scan spectrogram and persistence display applicable**



Ultra-fast scan time for entire frequency range

Long scan time for entire frequency range

CISPR 16 – FFT-BASED MEASURING RECEIVERS

Amendment 1:2010-06 to CISPR 16-1-1 (3rd Ed.)

► **Blackbox approach**

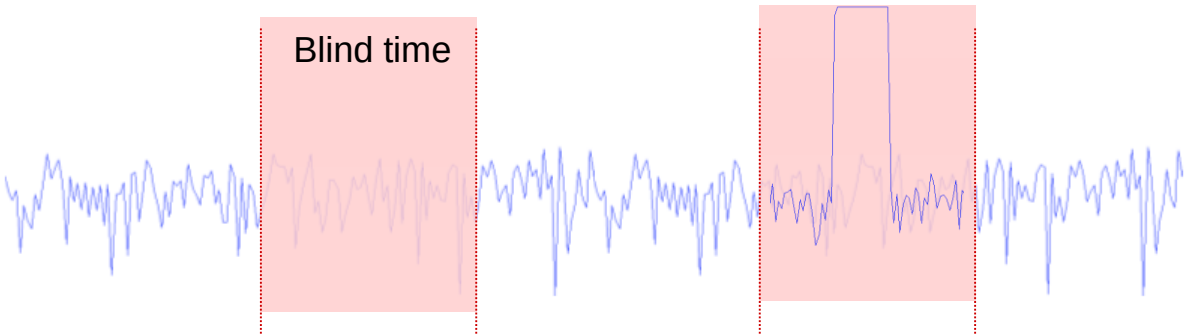
► FFT-based **measurement receiver** for compliance testing

"instrument such as a tunable voltmeter, an EMI receiver, a spectrum analyzer or an FFT-based measuring instrument, with or without preselection, that meets the relevant parts of this standard"

CISPR 16 – FFT-BASED MEASURING RECEIVERS

Amendment 1:2010-06 to CISPR 16-1-1 (3rd Ed.)

- ► With traditional instruments there is a blind time between capturing the signal
- ► Information might be and will be overlooked



”for EMI measurements, FFT-based measuring instruments shall sample and evaluate the signal continuously during the measurement time”

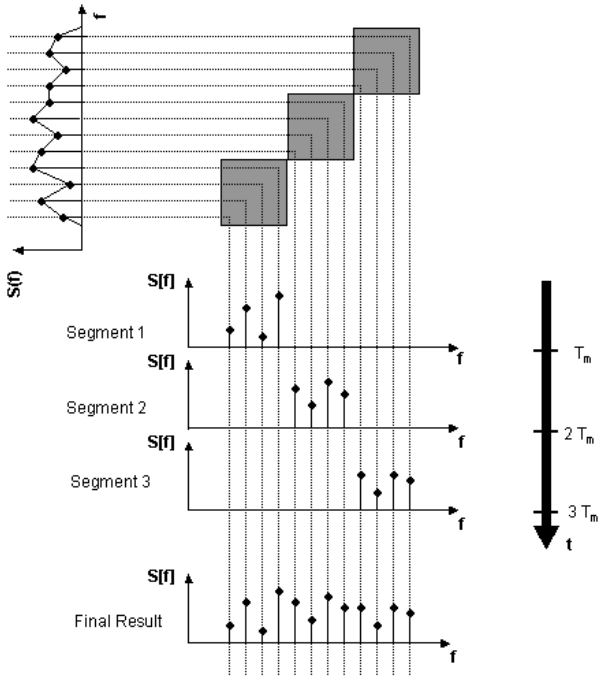
CISPR 16 – FFT-BASED MEASURING RECEIVERS

Amendments to CISPR 16-2-x

- FFT-based instruments (may) combine the parallel calculation frequencies and a stepped scan
- Frequency range of interest is subdivided into several segments, which are measured sequentially
- The scan time T_{scan} is

$$T_{scan} = T_m \times N_{seg}$$

- T_m is to be selected longer than the pulse repetition interval T_p for a correct measurement of a „BB“ spectrum



Source: CISPR 16-2-3:2016-09 (Ed.4)

CISPR 16 – FFT-BASED MEASURING RECEIVERS

More Speed with Time-Domain Scan

Frequency range	Weighting detector; measurement time; IF bandwidth; step width for stepped scan (SS) and Time Domain Scan (TD)	FFT-based measuring instrument R&S ESW	
		Stepped Scan	Time-domain Scan
CISPR Band B 150 kHz to 30 MHz	Pk, 100 ms; 9 kHz; SS: 4 kHz, TD: 2.25 kHz	12:35 min	0.11 s
CISPR Band B 150 kHz to 30 MHz	QP + CAV, 1 s, 9 kHz SS: 4 kHz, TD: 2.25 kHz	approx. 3.8 h	2 s
CISPR Bands C/D 30 to 1000 MHz	Pk, 10 ms, 120 kHz SS: 40 kHz, TD: 30 kHz	4:15 min	0.38 s
CISPR Bands C/D 30 to 1000 MHz	QP, 1 s, 120 kHz SS: 40 kHz, TD: 30 kHz	approx. 10 h	50 s
CISPR Bands C/D 30 to 1000 MHz	QP + CAV, 1 s, 9 kHz SS: 4 kHz, TD: 2.25 kHz	approx. 100 h	64 s

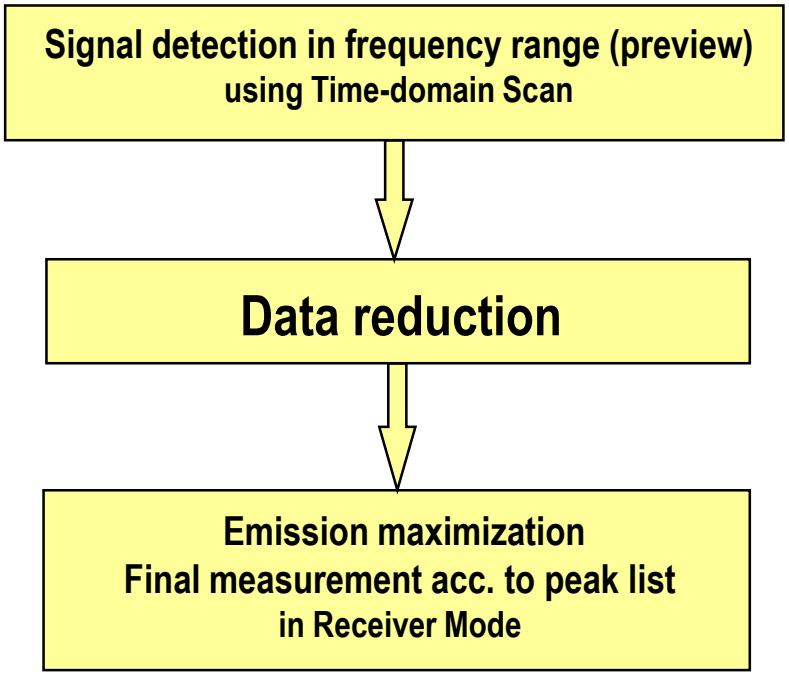
CISPR 16 – FFT-BASED MEASURING RECEIVERS

FFT-based measurement instrumentation

- **Applicability**
  - CISPR 32:2012 (Multimedia) — Applicable since 30.01.2012
  - CISPR 15:2013 (Lighting) — Applicable since 08.05.2013
  - CISPR 11:2015 (ISM) — Applicable since 09.06.2015
  - CISPR 14-1:2016 (Household) — Applicable since 10.08.2016
  - **CISPR 25:2016 (Automotive) — Applicable since 27.10.2016**
  - **CISPR 36:2020 (Automotive) — Applicable since 22.07.2020**
  - **CISPR 12:20xx (Automotive) — Publication of Ed. 7 expected in 2022**
  - Not applicable (Amendment 1 to CISPR 16-1-1:2010 not referenced) for CISPR 11:2009, **CISPR 12:2007**, CISPR13:2009 (5th Ed.), CISPR 14-1:2005, CISPR 15:2005, CISPR 22:2008 (6th Ed.) and CISPR 25:2008
    → But time domain scan can be used for preview measurements

CISPR 16 – FFT-BASED MEASURING RECEIVERS

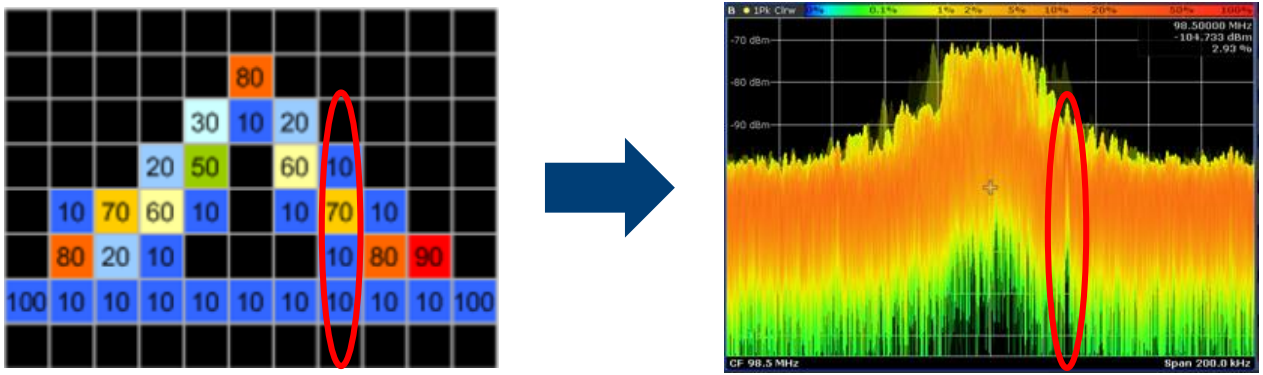
Applicability if latest CISPR 16-1-1 is not referenced



CISPR 16 – FFT-BASED MEASURING RECEIVERS

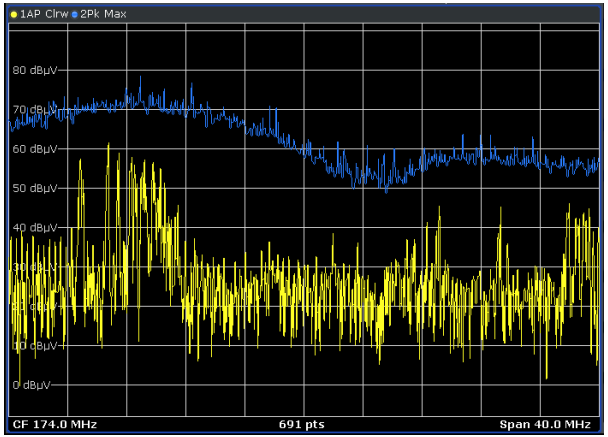
Persistence spectrum

- The trace color shows how often a signal occurs at a specific frequency and level
- Spectral histogram

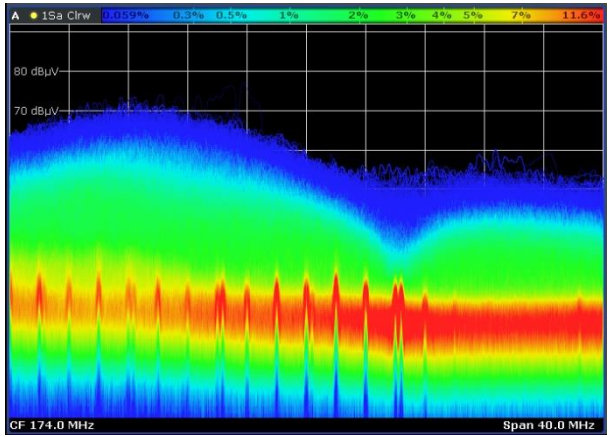


CISPR 16 – FFT-BASED MEASURING RECEIVERS

Persistence spectrum - practical use



Clear write display (yellow trace) Max hold display (blue trace) of a broadband interferer (windshield wiper motor) with conventional spectrum analysis

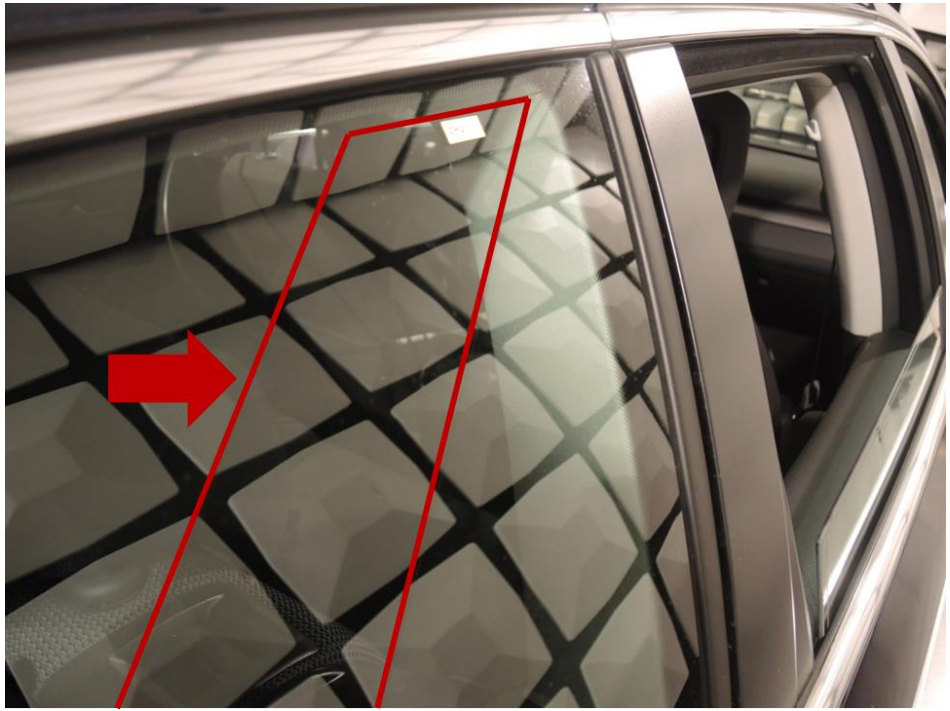


The same disturbance signal in persistence spectrum mode: A second pulsed disturbance signal is hidden by the broadband noise

CISPR 16 – FFT-BASED MEASURING RECEIVERS

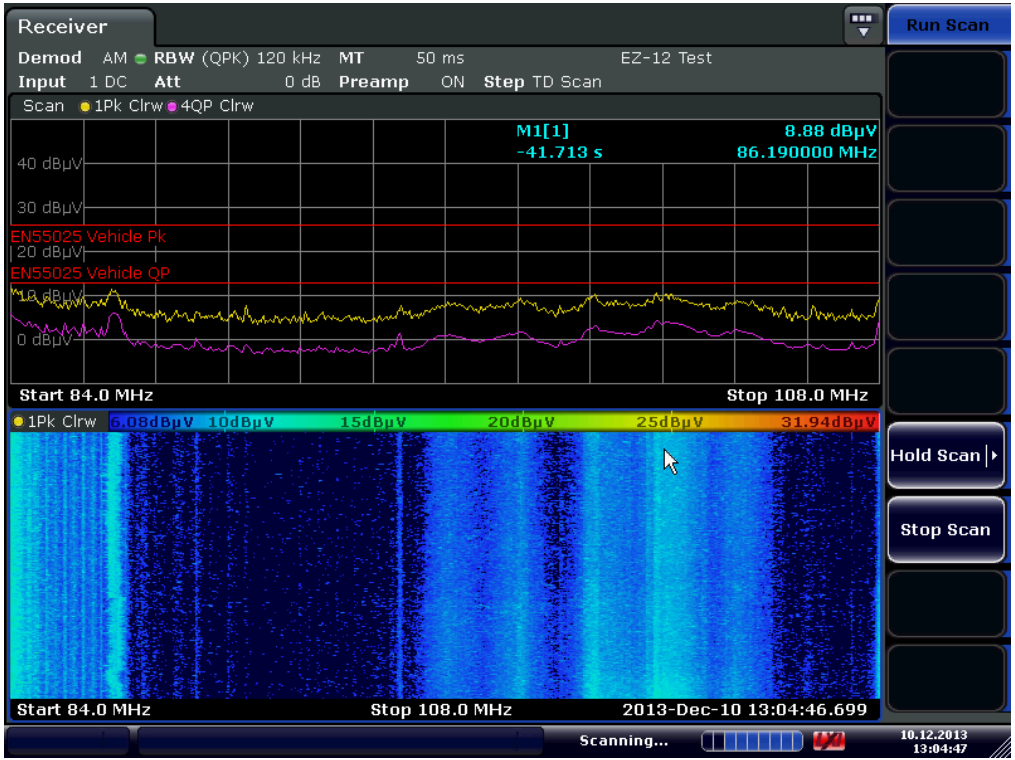
Scan spectrogram - practical use

- Antenna in rear window
- Impedance converter (e.g. R&S®EZ-12)
- Test Receiver



CISPR 16 – FFT-BASED MEASURING RECEIVERS

Scan spectrogram - practical use



Rear window wiper operation (green) shows broadband interference in range 84 MHz to 108 MHz

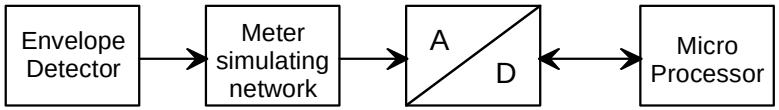
Water pump (red) shows broadband interference with high amplitude in the entire FM band

CISPR12

CISPR 16 – CISPR-AVERAGE DETECTOR

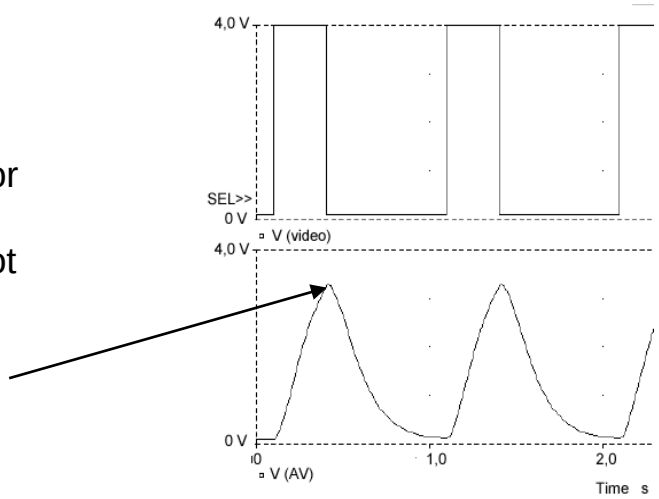
Linear CISPR-Average detector with meter time constant

- Band A/B = 160 ms, Band C/D/E = 100 ms)



For pulse-modulated signals with a PRF lower than the meter time constant, e.g. f_p < 6 Hz for Band A/B, the measurement result is not the average!

but the maximum of the output of the meter simulating network

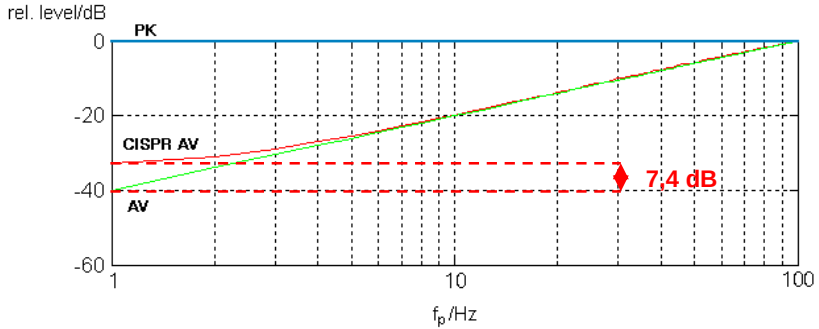


CISPR 16 – CISPR-AVERAGE DETECTOR

Example for pulse width = 10 ms, measurement time T_{meas} > 10 / f_p

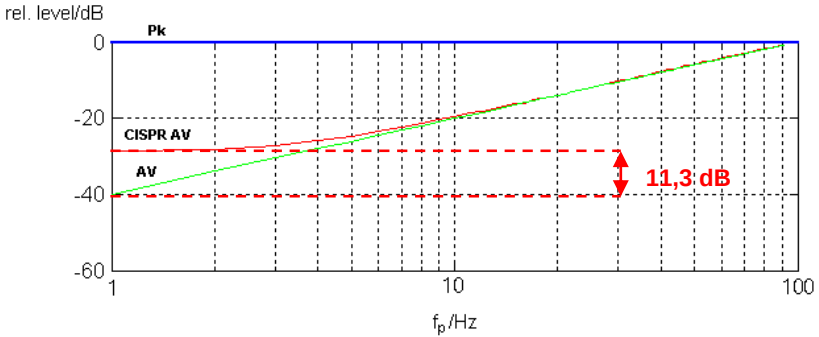
Band A/B:

T_{meter} = 160 ms



Band C/D/E:

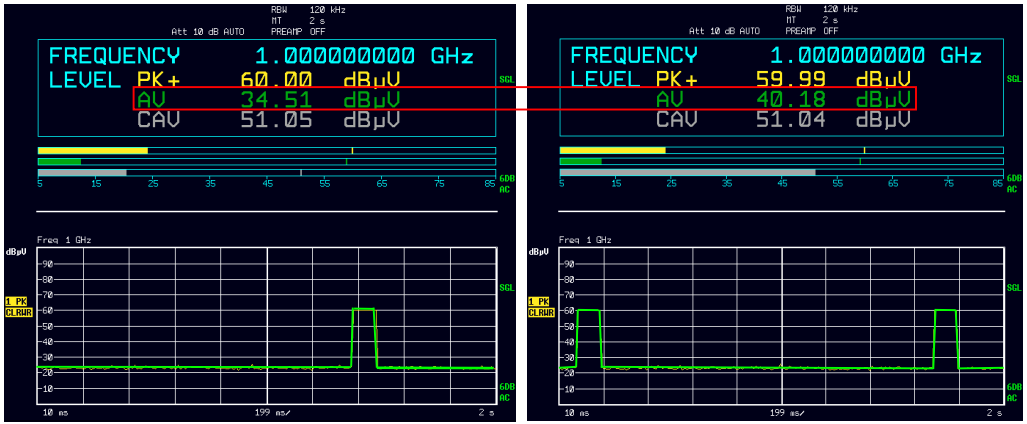
T_{meter} = 100 ms



CISPR 16 – CISPR-AVERAGE DETECTOR

Response to intermittent, unsteady and drifting narrowband disturbances

- **Using a linear average detector without meter time constant (AV) will result in a wrong weighted measurement**
- **A tolerance of ±1,0 dB is allowed**



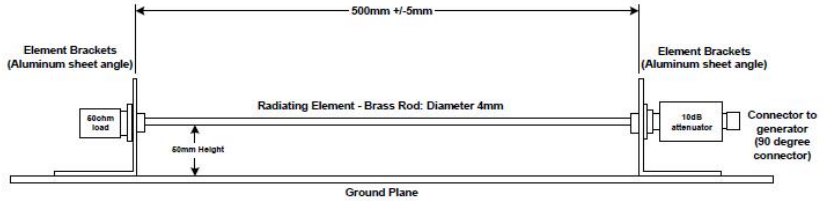
Pulse signal:
Duration=100 ms
Period=1,6 s

Receiver:
RBW=120 kHz
MT=2s

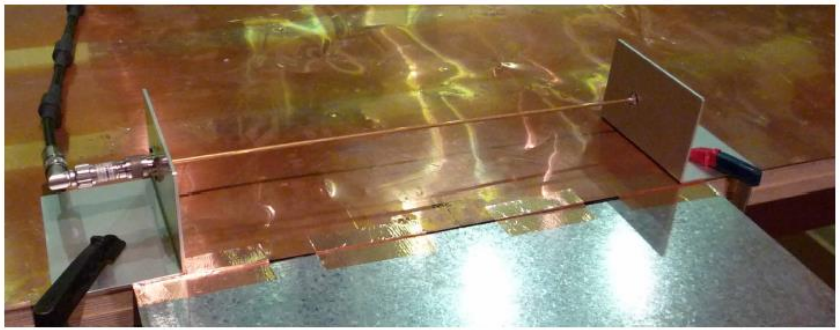
CISPR12

CISPR 25 – PROTECTION OF ON-BOARD RECEIVERS

Long wire method for chamber validation 150 kHz to 1 GHz



e J.8 - Radiator side view 50 Ω terminations



Source: CISPR 25:2016-10 (Ed.4)