VOLKSWAGEN

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TL 965

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Descriptors: EMC, short-distance interference suppression, long-distance interference suppression, radio interference suppression, interference emission

Interference Emission

Requirements

Preface

Additional tests necessary for evaluation and release are defined and required in the drawing, part-specific Technical Supply Specifications (TL), Performance Specifications or other documents.

Previous issues

TL 965: 1976-01, 1979-04, 1983-04, 1987-06, 1994-03, 1999-11, 2003-06, 2004-10, 2006-11, 2009-04, 2009-05

Changes

The following changes have been made compared with TL 965: 2009-05:

– Updated to reflect latest component and vehicle requirements

Contents

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1 Scope

These Technical Supply Specifications (TL) define requirements and tests concerned with electromagnetic compatibility (EMC) with the aim to limit transient emissions (radio interference suppression) of electric and electronic automotive components. The measuring methods and limit values specified in this TL standard are designed to ensure an interference-free reception of the high-frequency receivers operated in the vehicle.

The measuring methods and limit values described in this TL apply to all electric and electronic automotive components. Depending on the radio application in the vehicle, tests must be carried out in the specific frequency bands for radio and TV broadcasting, mobile telephony and mobile radio between 0,1 MHz and 2,69 GHz.

The requirements of TL 965 are not fulfilled unless the component and vehicle tests (also A 3 long-distance interference suppression) have been positively evaluated by the appropriate EMC department of the Volkswagen Group.

The measuring methods, measuring conditions, and measuring setups correspond extensively to the international standard CISPR 25 ""Vehicles, boats and internal combustion engines – radio disturbance characteristics – limits and methods of measurement for the protection of on-board receivers"" and were taken from this standard with the corresponding amendments; or this standard will be referred to. However, the specifications contained in this TL standard take precedence over the specifications in the above mentioned CISPR 25.

2 Terms and definitions

2.1 Short-term interference sources – permanent interference sources

Interferences that are not explicitly defined as short-term interference sources by the responsible department are considered as permanent interference sources and must be suppressed.

2.2 Definitions

ALSE	Absorber-lined shielded enclosure
AMPS	Advanced Mobile Phone System
AN	Artificial network
AV	Linear average-value detector as per CISPR 16-1-1 "Specification for radio-disturbance and immunity-measuring apparatus and methods – part 1-1: radio-disturbance and immunity-measuring apparatus – measuring apparatus" Use of the linear average value detector without consideration of the time constant of the display apparatus is also permissible.
BOS	Public safety organizations in Germany
BW	Intermediate frequency (IF) measurement bandwidth of the measuring receiver
CCC	Capacitive coupling clamp as per ISO 7637-3
CP	Current probe
CTE	Conducted transient emission
CV	Capacitive voltage
GPS	Global Positioning System
GSM	Global System for Mobile Communications

IBK	Industry assembly kit (German abbreviation) – component that can be employed at different automobile manufacturers
IMT-2000	International Mobile Telecommunications-2000 (3G, 3rd generation mobile telecommunications)
LTE	Long Term Evolution (4G, 4th generation mobile telecommunications)
NFC	Near field communication
PDC	Personal Digital Communication
PE	Polyethylene
PK	Peak value detector according to CISPR 16-1-1
PP	Polypropylene
QP	Quasi-peak value detector according to CISPR 16-1-1
RE	Radiated emission
SDARS	Satellite Digital Audio Radio Service
SL	Stripline
SRD	Short range devices
STR	Stripline method
TEM	Transverse electromagnetic mode
TETRA	Terrestrial Trunked Radio
UMTS	Universal Mobile Telecommunications System
WCDMA	Wideband Code Division Multiple Access

3 General requirements – HF emissions from vehicle and component measurements

General requirements as per CISPR 25, additional or deviating:

3.1 Description of the operating states

The responsible EMC department of Volkswagen/Audi will decide on the relevance of individual operating states within the framework of the EMC project meeting to be held according to the EMC Section of the performance specifications.

In addition to a component's normal operating condition (e.g., engine running, terminal 15 ON; or electric driving mode for electric/hybrid vehicles), define in the test plan other operating conditions in which the component (DUT) is subject to maximum radio disturbance. The suppler is to provide proof, for example, for different voltages in the electric system, by taking measurements.

The supplier must present the various operating states before the first tests are carried out on the component. The supplier must also analyze the affect of the states on electromagnetic interference in consultation with the appropriate Volkswagen/Audi departments.

The supplier must always test components as per section 5.

To enable the component tests to be verified by the appropriate Volkswagen/Audi EMC department, the supplier must provide test equipment that enables this department to simulate at least the operating states mentioned above and monitor these states during testing. The selected operating states and test setups must be documented in the test report in detail.

3.2 Test documentation

For the EMC relevance to be assessed, the following mandatory documents must be presented upon commencement of development:

- System designation
- System description including representation of system functions
- Circuit diagram, component location drawing and bill of materials
- Operating states with sequence descriptions (e.g., switch-on/-off procedures, static/dynamic states)
- Description of sub-circuitry (sub-systems, sensors, actuators)
- System variants and codings
- Interfaces to other vehicle components
- System-inherent fault handling and diagnostic function
- Documentation of the EMC measures (e.g. filter and protective circuitry for inputs/outputs as well as supply lines, shielding measures)

Prior to delivery of the samples to be tested, the following documents must be presented in addition:

- Exact schedule of the planned EMC component tests and the planned test location (laboratory)
- deviations from the TL's requirements as agreed upon between the appropriate Volkswagen Group departments and the supplier
- Meaningful, complete EMC qualification report for the respective sample version
- Hardware/software version including description/record of the EMC measures

3.3 Test conditions

The maximum frequency increments and minimum measuring times are specified in table 1.

If necessary, the measuring time must be sufficiently extended to capture the interference characteristics of the DUT (this must also be taken into account for fast Fourier transform (FFT) measurements).

Table 1 – Maximum frequency steps and minimum measuring times

BW	PK		QP		AV	
	Maximum increment	Minimum measuring time	Maximum increment	Minimum measuring time	Maximum increment	Minimum measuring time
f in kHz		t in ms		t in ms		t in ms
9/10	≤ 0,5 × BW	50	≤ 5 × BW	1 000	≤ 0,5 × BW	50
120	≤ 0,5 × BW	5	≤ 5 × BW	1 000	≤ 0,5 × BW	5
1 000	≤ 0,5 × BW	50	–	–	≤ 0,5 × BW	50

Fast emission measuring methods using the fast Fourier transform (FFT) may be used to shorten measuring times. It must be demonstrated that the implemented detectors and measuring bandwidths comply with the requirements of CISPR 16-1-1. Deviation: An increased displayed value for pulse repetition rates below 20 Hz is permissible when verifying the detector value of pulse signals that have differing pulse repetition rates (e.g., for the QP detector).

3.4 Temperatures

Operating temperature range	acc. to drawing, Performance Specifications or Technical Supply Specification
Test temperature range	(23 ± 5) °C; operating temperature in special cases

3.5 Run-in time

The electric components to be tested must be subjected to a 15-minute run-in time under specified load (as per drawing or Performance Specifications) and test voltage.

4 HF emissions – vehicle measurement (vehicle test)

4.1 Frequency range during vehicle measurement

Frequency range	0,1 MHz to 2 690 MHz

4.2 Emission measurement at the vehicle antennas (vehicle emission test)

Emission measurements at the vehicle antennas must be conducted as per CISPR 25 in order to protect receivers operated in the vehicle.

4.3 Requirements

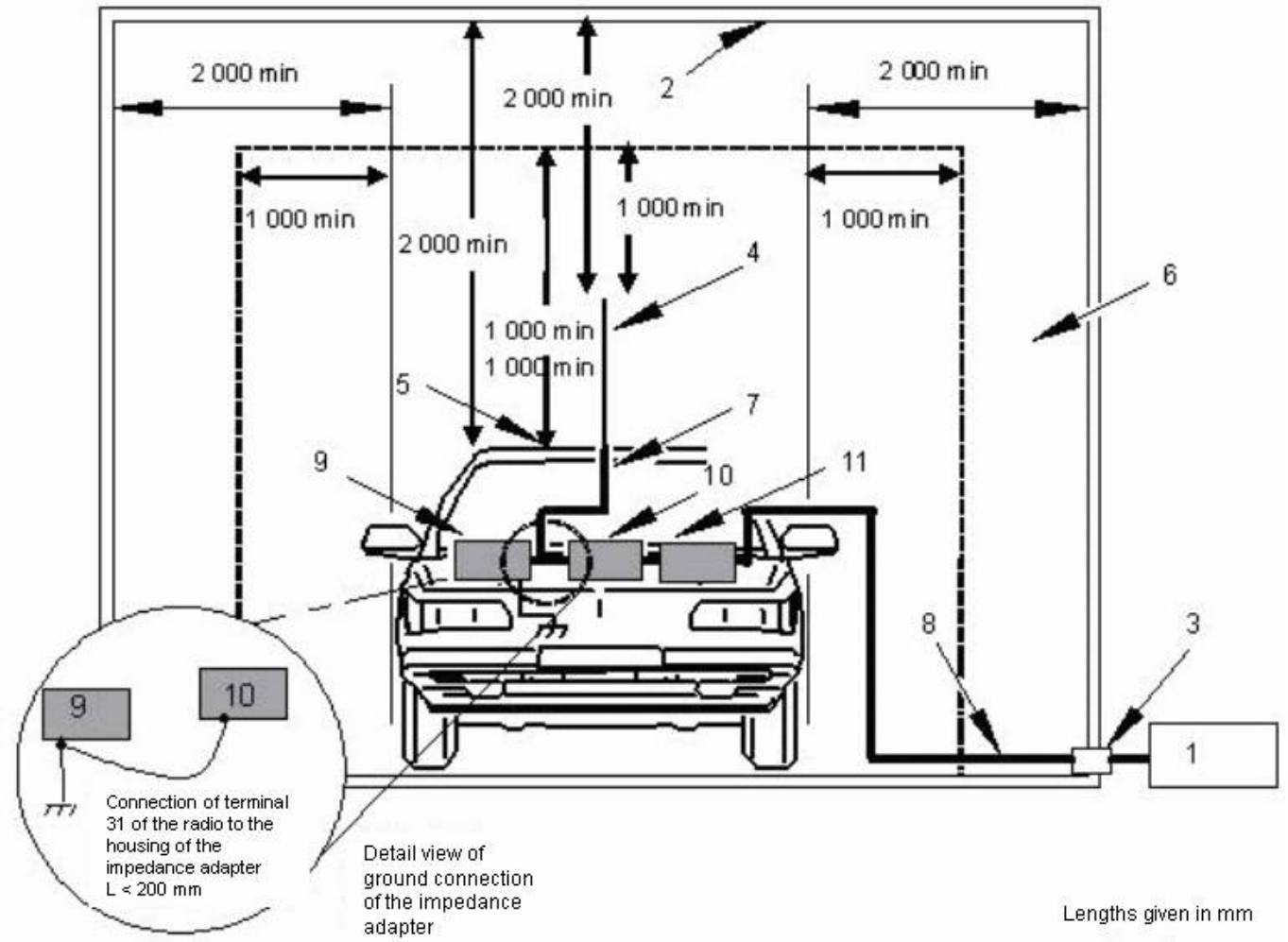
The measurement receiver settings and limits are defined in table 2, table 3, and table 4. The emissions must comply with all the specified limits (PK, AV, and QP) for all services and bands that are to be measured. Unless otherwise specified, all services and bands from table 2, table 3, and table 4 must be tested.

The high-frequency (HF) emission measurements in the vehicle are carried out as per CISPR 25. In the case of deviations, the specifications in this TL apply.

4.4 Measuring setup

The measuring setup is described in CISPR 25.

There must be at least 1 m distance between the vehicle edges or components (e.g. antenna) and the absorber tips. Further dimensional specifications see figure 1.



Legend

1	Measuring instrument[1)]
2	Anechoic chamber
3	Lead-through connection
4	Antenna (see section 4.5).
5	DUT
6	Typical absorber material
7	Coaxial antenna cable
8	High-quality double-shielded coaxial cable (50 Ω)
9	Car radio housing
10	Impedance adapter[2)] Antenna adapter[3)]
11	Optical transmission link for AM radio band (if necessary)

Figure 1 – Measurement setup: Vehicle measuring – short-distance interference suppression

1) For medium-wave (MW) measurements, place the measuring receiver in the anechoic chamber, provided no optical transmission link is used or there is no other way to take an influence-free measurement.

2) Must be used depending on the antenna/radio impedance in the MW range (e.g., impedance adapter, type 152-4107, BR2 from TRAWID, EZ12 from R&S, or similar)

3) For phantom-powered vehicle antennas, such as MW, VHF, DAB, TV, or GPS measurements

4.5 Antennas and related components

For vehicle measurements, the antennas and mounting locations intended for application in production must be used. The measuring receiver is connected to the impedance adapter, depending on the antennas/radio impedance for the MW measurements; the measuring receiver is connected to the antenna adapter (dummy) at the installation location of the respective receiver for VHF, DAB, TV, and GPS measurements.

The adapter is connected to ground as per figure 1, low-impedance with a maximum length of 200 mm.

4.6 Measurement receiver settings and limits for vehicle measurements

The limits specified in table 2 apply to passive and active antennas.

Table 2 – Measurement receiver settings and limits (vehicle emission test)

Test no.:	Service or band	Frequency	PK		QP		AV		Ant. pos.[a)]
			Limit	BW	Limit	BW	Limit	BW	
		f in MHz	U/dB (µV)	f in kHz	U/dB (µV)	f in kHz	U/dB (µV)	f in kHz	
Broadcast									
1	LW	0,15 ... 0,28	LW is not used in the Volkswagen Group						
2	MW	0,52 ... 1,73	–	–	7	9/10	0	9/10	3
3	SW 75 m	3,85 ... 4,0	SW is not used in the Volkswagen Group						
4	SW 49 m	5,8 ... 6,3							
5	SW 41 m	7,1 ... 7,6							
6	SW 31 m	9,3 ... 10,0							
7	SW 25 m	11,5 ... 12,1							
8	NFC SW 22 m	13,5 ... 13,9	–	–	7	9/10	0	9/10	4
9	SW 19 m	15,0 ... 15,8	SW is not used in the Volkswagen Group						
10	SW 16 m	17,4 ... 17,9							
11	SW 15 m	18,9 ... 19,1							
12	SW 13 m	21,4 ... 21,9							
13	SW 11 m	25,6 ... 26,1							
14	VHF	76 ... 108	–	–	7	120	0	120	3

a) Antenna position, if the antenna installation locations are not yet defined or unknown
Ant. positions 1: roof, front; 2: roof, center; 3: roof, rear; 4: vehicle interior, between the front seats

The limits specified in table 3 apply to passive antennas. With active antennas, proceed as follows: When taking a preliminary noise measurement, use an AV detector to measure the system noise

(antenna amplifier, cable, measurement receiver, etc.) in a vehicle that is electrically shut-down but has an active antenna system. "System noise + 6 dB" applies as a limit.

Table 3 – Measurement receiver settings and limits (vehicle emission test)

Test no.:	Service or band	Frequency	PK		QP		AV		Ant. pos.[a]
			Limit	BW	Limit	BW	Limit	BW	
		f in MHz	U/dB (µV)	f in kHz	U/dB (µV)	f in kHz	U/dB (µV)	f in kHz	
Broadcast – digital									
15	DAB	174 ... 241	–	–	–	–	10	1 000	3
16	DAB (L band)	1 452 ... 1 492	–	–	–	–	10	1 000	3
17	SDARS	2 320 ... 2 345	–	–	–	–	10	1 000	3
18	TV I	54 ... 88	TV I is not used in the Volkswagen Group						
19	TV II	90 ... 108	–	–	–	–	10	1 000	3
20	TV III	170 ... 230	–	–	–	–	10	1 000	3
21	TV IV/V	470 ... 806	–	–	–	–	10	1 000	3

a) Antenna position, if the antenna installation locations are not yet defined or unknown
Ant. positions 1: roof, front; 2: roof, center; 3: roof, rear; 4: vehicle interior, between the front seats

The limits specified in table 4 apply to passive antennas. With active antennas, proceed as follows for the "GPS" band (test no. 38): In a preliminary noise measurement, the system noise (antenna amplifier, cable, measurement receiver, etc.) must be measured with an AV detector in a vehicle that is electrically shut-down, but with an active antenna system. "System noise + 3 dB" applies as a limit.

Table 4 – Measurement receiver settings and limits (vehicle emission test)

Test no.:	Service or band	Frequency	PK		QP		AV		Ant. pos.[a]
			Limit	BW	Limit	BW	Limit	BW	
		f in MHz	U/dB (µV)	f in kHz	U/dB (µV)	f in kHz	U/dB (µV)	f in kHz	
Mobile and other services									
22	125 kHz	0,1 ... 0,15	23	9/10	–	–	–	–	3
23[b]	CB radio	26,5 ... 29,7	30	9/10	–	–	10	9/10	3
24	4 m/BOS	84,015 ... 87,255	33	120	–	–	0	9/10	2
25	2 m/taxi	146 ... 164	33	120	–	–	0	9/10	1
26	2 m/BOS	167,56 ... 169,38	33	120	–	–	0	9/10	1
27	2 m/BOS	172,16 ... 173,98	33	120	–	–	0	9/10	1
28	SRD	313 ... 317	15	9/10	–	–	-5	9/10	1
29	Trunked radio	390 ... 400	20	120	–	–	0	120	2
30	Trunked radio	420 ... 430	20	120	–	–	0	120	2
31	SRD	433 ... 435	15	9/10	–	–	-5	9/10	1
32	Trunked radio	460 ... 470	20	120	–	–	0	120	2

Test no.:	Service or band	Frequency	PK		QP		AV		Ant. pos.[a]
			Limit	BW	Limit	BW	Limit	BW	
		f in MHz	U/dB (µV)	f in kHz	U/dB (µV)	f in kHz	U/dB (µV)	f in kHz	
33	LTE	791 ... 821	–	–	–	–	10	1000	2
34	PDC D-AMPS	851 ... 894	–	–	–	–	6	120	1
35	SRD	868 ... 876	15	9/10	–	–	-5	9/10	1
36	GSM-900	925 ... 960	–	–	–	–	6	120	3
37	PDC	1477 ... 1501	In the Volkswagen Group, PDC is not used in this frequency range						
38	GPS	1568 ... 1583	–	–	–	–	-5	9/10	3
39	GSM-1800	1805 ... 1880	–	–	–	–	6	120	3
40	UMTS	1900 ... 1920	–	–	–	–	10	1000	3
41	GSM-1900	1930 ... 1990	–	–	–	–	6	120	3
42	UMTS	2010 ... 2025	–	–	–	–	10	1000	3
43	UMTS, WCDMA	2110 ... 2170	–	–	–	–	10	1000	3
44	Bluetooth, WLAN	2402 ... 2497	–	–	–	–	10	1000	4
45	IMT-2000	2500 ... 2570	–	–	–	–	10	1000	3
46	IMT-2000/ LTE	2620 ... 2690	–	–	–	–	10	1000	3

a) Antenna position, if the antenna installation locations are not yet defined or unknown
Ant. positions 1: roof, front; 2: roof, center; 3: roof, rear; 4: vehicle interior, between the front seats

b) The main area of application is in heavy commercial vehicles.

5 Component measurement method

5.1 Overview of emission tests and frequency ranges

Overview of emission tests and frequency ranges (see table 5).

Table 5 – Overview of mandatory and optional component measuring methods

Measuring methods mandatory for release	0,1 MHz		30 MHz		108 MHz		245 MHz		960 MHz		2690 MHz
Component measuring methods to be conducted for release											
Measurement at the artificial network (AN test)											
Measurement with antennas (RE test)											
Optional measuring methods (to be specified in the test plan)											
Capacitive voltage measurement (CV test, optional)											
Measurement with clamp-on current probe (CP test, optional)											
Measurement with TEM cell (TEM test, optional)											
Measurement with the stripline (SL test, optional)											
Gray fields mark the frequency range to be measured with the respective measuring method					Do not measure in the white field ranges with the respective measuring method						

5.2 Limit classes

The frequency bands to be tested and the limits to be used must be defined in the Performance Specifications, under consideration of the vehicle variants, the receiving systems, and the packaging situation. The limit classes 3, 4, and 5 are available for this purpose.

For IBK components, all frequency bands must be tested and the limit class 5 must be adhered to and this adherence verified.

If only limit classes 4 or 3 are required (deviating from IBK requirements), this must only be done by reducing the population (e.g., installing fewer components) with the goal of reducing costs. It must be possible to achieve limit class 5 for IBK components by simply adding extra components to the population, without changing the printed circuit board (PCB) layout.

5.3 HF emissions – measurement at the artificial network (AN test)

The HF emissions on supply lines must be measured as per CISPR 25.

5.3.1 Test setup

The test setup is described in CISPR 25.

5.3.2 Test conditions

The standard test conditions must be used as per section 3.3 of this TL.

If the DUT has several power supplies, each power supply must be measured individually.

5.3.3 Requirements

All emission limits must be adhered to for the bands defined in table 6.

Table 6 – Measurement receiver settings and limits (AN test)

Test no.:	Service or band	Frequency	PK				QP				AV			
			Limit			BW	Limit			BW	Limit			BW
		f in MHz	U/dB (µV)			f in kHz	U/dB (µV)			f in kHz	U/dB (µV)			f in kHz
			Class				Class				Class			
			3	4	5		3	4	5		3	4	5	
Base limits														
B1		0,28 ... 0,52	91 - 59,51 × (lg(f/0,28)[a]			9/10	-			-	81 - 59,51 × (lg(f/0,28)[a]			9/10
B2		0,52 ... 30	75			9/10	-			-	65			9/10
B3		30 ... 108	65			120	-			-	55			120
Broadcast														
1[b]	LW	0,15 ... 0,28	-			-	77	67	**57**	9/10	70	60	**50**	9/10
2	MW	0,52 ... 1,73	-			-	57	49	**41**	9/10	50	42	**34**	9/10
3[b]	SW 75 m	3,85 ... 4,0	-			-	52	46	**40**	9/10	45	39	**33**	9/10
4[b]	SW 49 m	5,8 ... 6,3	-			-	52	46	**40**	9/10	45	39	**33**	9/10
5[b]	SW 41 m	7,1 ... 7,6	-			-	52	46	**40**	9/10	45	39	**33**	9/10
6[b]	SW 31 m	9,3 ... 10,0	-			-	52	46	**40**	9/10	45	39	**33**	9/10
7[b]	SW 25 m	11,5 ... 12,1	-			-	52	46	**40**	9/10	45	39	**33**	9/10
8	NFC SW 22 m	13,5 ... 13,9	-			-	52	46	**40**	9/10	45	39	**33**	9/10
9[b]	SW 19 m	15,0 ... 15,8	-			-	52	46	**40**	9/10	45	39	**33**	9/10
10[b]	SW 16 m	17,4 ... 17,9	-			-	52	46	**40**	9/10	45	39	**33**	9/10
11[b]	SW 15 m	18,9 ... 19,1	-			-	52	46	**40**	9/10	45	39	**33**	9/10
12[b]	SW 13 m	21,4 ... 21,9	-			-	52	46	**40**	9/10	45	39	**33**	9/10
13[b]	SW 11 m	25,6 ... 26,1	-			-	52	46	**40**	9/10	45	39	**33**	9/10
14	VHF	76 ... 108	-			-	31	25	**19**	120	24	18	**12**	120
Broadcast – digital														
18[b]	TV I	54 ... 88	60	54	**48**	1 000	-			-	45	39	**33**	1 000
19	TV II	90 ... 108	55	49	**43**	1 000	-			-	40	34	**28**	1 000
Mobile and other services														
22	125 kHz	0,1 ... 0,15	93	83	**73**	9/10	-			-	-	-	-	-
23[c]	CB radio	26,5 ... 29,7	75	69	**63**	9/10	-			-	63	53	**43**	9/10
24	4 m/ BOS	84,015 ... 87,255	53	47	**41**	120	-			-	20	14	**8**	9/10

Test no.:	Service or band	Frequency	PK				QP				AV			
			Limit			BW	Limit			BW	Limit			BW
		f in MHz	U/dB (µV)			f in kHz	U/dB (µV)			f in kHz	U/dB (µV)			f in kHz
			Class				Class				Class			
			3	4	5		3	4	5		3	4	5	
In principle, measurements may be conducted with the peak detector in all ranges. If the peak measured value lies below the quasi-peak limit, the quasi-peak limit is fulfilled.														
Limit class 3 may be selected for short-term interferers (e.g., adjusting motors) under consideration of section 2.1 and section 5.2 "Limit classes".														
For interferences that can be attributed to brush sparking (commutator interferers), the high-voltage ignition system, and timed injection systems (diesel engines, Otto engines), limit class 3 may be selected for the MW range when measuring with the quasi-peak detector under consideration of section 5.2 "Limit classes". The average limit must be complied with unchanged.														

a) In the formulae, the frequency f must be entered in MHz; "lg" denominates the logarithm to the base 10.

b) The requirement applies only to the IBK component

c) The main area of application is in heavy commercial vehicles.

5.4 HF emissions – measurement with antennas (RE test)

The radiated HF emissions must be measured with antennas as per CISPR 25. Deviating from CISPR 25, HF emission measurements may also be conducted in an anechoic chamber with floor absorbers as an alternative.

5.4.1 Test setup

The test setup is described in CISPR 25.

5.4.2 Test conditions

The standard test conditions must be used as per section 3.3 of this TL.

5.4.3 Requirements

All emission limits must be adhered to for the bands defined in table 7. The base limit is based on the values of the ECE-R 10[1] regulation.

Table 7 – Measurement receiver settings and limits (RE test)

Test no.:	Service or band	Frequency	PK				QP				AV			
			Limit			BW	Limit			BW	Limit			BW
		f in MHz	E/dB (µV/m)			f in kHz	E/dB (µV/m)			f in kHz	E/dB (µV/m)			f in kHz
			Class				Class				Class			
			3	4	5		3	4	5		3	4	5	
Base limits														
B4		0,28 ... 30	62			9/10	-			-	52			9/10

Test no.:	Service or band	Frequency	PK				QP				AV			
			Limit			BW	Limit			BW	Limit			BW
		f in MHz	E/dB (µV/m)			f in kHz	E/dB (µV/m)			f in kHz	E/dB (µV/m)			f in kHz
			Class				Class				Class			
			3	4	5		3	4	5		3	4	5	
B5		30 ... 75	62 - 25,13 × (lg(f/30)[a]			120	-			-	52 - 25,13 × (lg(f/30)[a]			120
B6		75 ... 400	52 + 15,13 × (lg(f/75)[a]			120	-			-	42 + 15,13 × (lg(f/75)[a]			120
B7		400 ... 1 000	63			120	-			-	53			120
Broadcast														
1[b]	LW	0,15 ... 0,28	-			-	48	38	**28**	9/10	41	31	**21**	9/10
2	MW	0,52 ... 1,73	-			-	41	33	**25**	9/10	34	26	**18**	9/10
3[b]	SW 75 m	3,85 ... 4,0	-			-	37	31	**25**	9/10	30	24	**18**	9/10
4[b]	SW 49 m	5,8 ... 6,3	-			-	37	31	**25**	9/10	30	24	**18**	9/10
5[b]	SW 41 m	7,1 ... 7,6	-			-	37	31	**25**	9/10	30	24	**18**	9/10
6[b]	SW 31 m	9,3 ... 10,0	-			-	37	31	**25**	9/10	30	24	**18**	9/10
7[b]	SW 25 m	11,5 ... 12,1	-			-	37	31	**25**	9/10	30	24	**18**	9/10
8	NFC SW 22 m	13,5 ... 13,9	-			-	37	31	**25**	9/10	30	24	**18**	9/10
9[b]	SW 19 m	15,0 ... 15,8	-			-	37	31	**25**	9/10	30	24	**18**	9/10
10[b]	SW 16 m	17,4 ... 17,9	-			-	37	31	**25**	9/10	30	24	**18**	9/10
11[b]	SW 15 m	18,9 ... 19,1	-			-	37	31	**25**	9/10	30	24	**18**	9/10
12[b]	SW 13 m	21,4 ... 21,9	-			-	37	31	**25**	9/10	30	24	**18**	9/10
13	SW 11 m	25,6 ... 26,1	-			-	37	31	**25**	9/10	30	24	**18**	9/10
14	VHF	76 ... 108	-			-	31	25	**19**	120	24	18	**12**	120
Broadcast – digital														
15	DAB	174 ... 241	44	38	**32**	1 000	-			-	34	28	**22**	1 000
16	DAB (L band)	1452 ... 1492	57	51	**45**	1 000	-			-	47	41	**35**	1 000
17	SDARS	2320 ... 2345	68	62	**56**	1 000	-			-	58	52	**46**	1 000
18[b]	TV I	54 ... 88	50	44	**38**	1 000	-			-	35	29	**23**	1 000
19	TV II	90 ... 108	49	43	**37**	1 000	-			-	34	28	**22**	1 000
20	TV III	170 ... 230	49	43	**37**	1 000	-			-	34	28	**22**	1 000
21	TV IV/V	470 ... 806	56	50	**44**	1 000	-			-	41	35	**29**	1 000
Mobile and other services														
22	125 kHz	0,1 ... 0,15	61	51	**41**	9/10	-			-	-	-	-	-
23[c]	CB radio	26,5 ... 29,7	60	54	**48**	9/10	-			-	40	34	**28**	9/10

Test no.:	Service or band	Frequency	PK				QP				AV			
			Limit			BW	Limit			BW	Limit			BW
		f in MHz	E/dB (µV/m)			f in kHz	E/dB (µV/m)			f in kHz	E/dB (µV/m)			f in kHz
			Class				Class				Class			
			3	4	5		3	4	5		3	4	5	
24	4 m/ BOS	84,015 ... 87,255	47	41	**35**	120	-			-	14	8	**2**	9/10
25	2 m/taxi	146 ... 164	47	41	**35**	120	-			-	14	8	**2**	9/10
26	2 m/ BOS	167,56 ... 169,38	47	41	**35**	120	-			-	14	8	**2**	9/10
27	2 m/ BOS	172,16 ... 173,98	47	41	**35**	120	-			-	14	8	**2**	9/10
28	SRD	313 ... 317	46	40	**34**	9/10	-			-	26	20	**14**	9/10
29	Trunked radio	390 ... 400	51	45	**39**	120	-			-	31	25	**19**	120
30	Trunked radio	420 ... 430	51	45	**39**	120	-			-	31	25	**19**	120
31	SRD	433 ... 435	46	40	**34**	9/10	-			-	26	20	**14**	9/10
32	Trunked radio	460 ... 470	51	45	**39**	120	-			-	31	25	**19**	120
33	LTE	791 ... 821	61	55	**49**	1 000	-			-	41	35	**29**	1 000
34	PDC, D-AMPS	851 ... 894	63	57	**51**	120	-			-	43	37	**31**	120
35	SRD	868 ... 876	52	46	**40**	9/10	-			-	32	26	**20**	9/10
36	GSM-900	925 ... 960	63	57	**51**	120	-			-	43	37	**31**	120
37[b)]	PDC	1477 ... 1501	63	57	**51**	120	-			-	43	37	**31**	120
38	GPS	1568 ... 1583	-			-	-			-	32	26	**20**	9/10
39	GSM-1800	1805 ... 1880	63	57	**51**	120	-			-	43	37	**31**	120
40	UMTS	1900 ... 1920	67	61	**55**	1 000	-			-	47	41	**35**	1 000
41	GSM-1900	1930 ... 1990	63	57	**51**	120	-			-	43	37	**31**	120
42	UMTS	2010 ... 2025	67	61	**55**	1 000	-			-	47	41	**35**	1 000
43	UMTS, WCDMA	2110 ... 2170	67	61	**55**	1 000	-			-	47	41	**35**	1 000
44	Blue-tooth, WLAN	2402 ... 2497	78	72	**66**	1 000	-			-	58	52	**46**	1 000
45	IMT-2000	2500 ... 2570	78	72	**66**	1 000	-			-	58	52	**46**	1 000

Test no.:	Service or band	Frequency	PK				QP				AV			
			Limit			BW	Limit			BW	Limit			BW
		f in MHz	E/dB (µV/m)			f in kHz	E/dB (µV/m)			f in kHz	E/dB (µV/m)			f in kHz
			Class				Class				Class			
			3	4	5		3	4	5		3	4	5	
46	IMT-2000/ LTE	2620 ... 2690	78	72	66	1 000	-			-	58	52	46	1 000
In principle, measurements with the peak detector may be conducted in all ranges. If the peak measured value lies below the quasi-peak limit, the quasi-peak limit is fulfilled.														
Limit class 3 may be selected for short-term interferers (e.g., adjusting motors) under consideration of section 2.1 and section 5.2 "Limit classes".														
For interferences that can be attributed to brush sparking (commutator interferers), the high-voltage ignition system, and timed injection systems (diesel engines, Otto engines), limit class 3 may be selected for the MW range when measuring with the quasi-peak detector under consideration of section 5.2 "Limit classes". The average limit must be complied with unchanged.														

a) In the formulae, the frequency f must be entered in MHz; "lg" denominates the logarithm to the base 10.

b) The requirement applies only to the IBK component

c) The main area of application is in heavy commercial vehicles.

5.5 HF emissions – capacitive voltage measurement (CV test, optional)

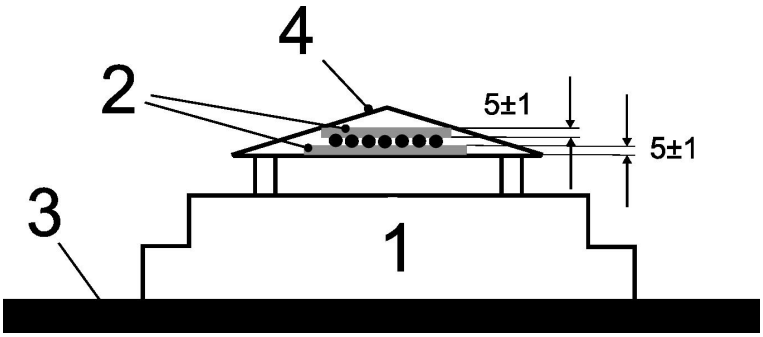
The HF emissions must be measured on all cables with a capacitive coupling clamp, using an impedance adapter (e.g., type 152-4107, BR2 from TRAWID, EZ12 from R&S, or similar).

5.5.1 Test setup

The test must be conducted in a shielded chamber.

A capacitive coupling clamp (CCC) as per ISO 7637-3 must be used. The cables must be placed between two (5 ± 1) mm high spacer strips made of non-conductive material with low relative permittivity ($\varepsilon_r \leq 1{,}4$) (see figure 2).

All dimensions in mm.



Legend

1 Capacitive coupling clamp as per ISO 7637-3
2 Spacer strips with low relative permittivity ($\varepsilon_r \leq 1{,}4$)
3 Ground plate
4 Septum

Figure 2 – Coupling clamp (CCC) as per ISO 7637-3 with spacer strips (CV test)

The output impedance of the impedance adapter must be 50 Ω. Optional capacitive loading of the impedance adapter input by a capacitor to ground, and/or a capacitor in series circuit to adjust to the sensitivity of the impedance adapter used, is permissible (typical values between 1 pF and 3 nF).

The impedance adapter must be connected with the measuring point of the coupling clamp by means of a cable that is as short as possible.

A measurement of the test setup system insertion loss (IL) must be conducted as per section 5.5.2; the requirements as per section 5.5.3 must be adhered to.

The measured system IL, including all cable attenuations, must be taken into account during the measurements as a corrective factor (all variables in dB):

$$U = U_{meas.} + A_{cable} + A_{CCC} \quad (1)$$

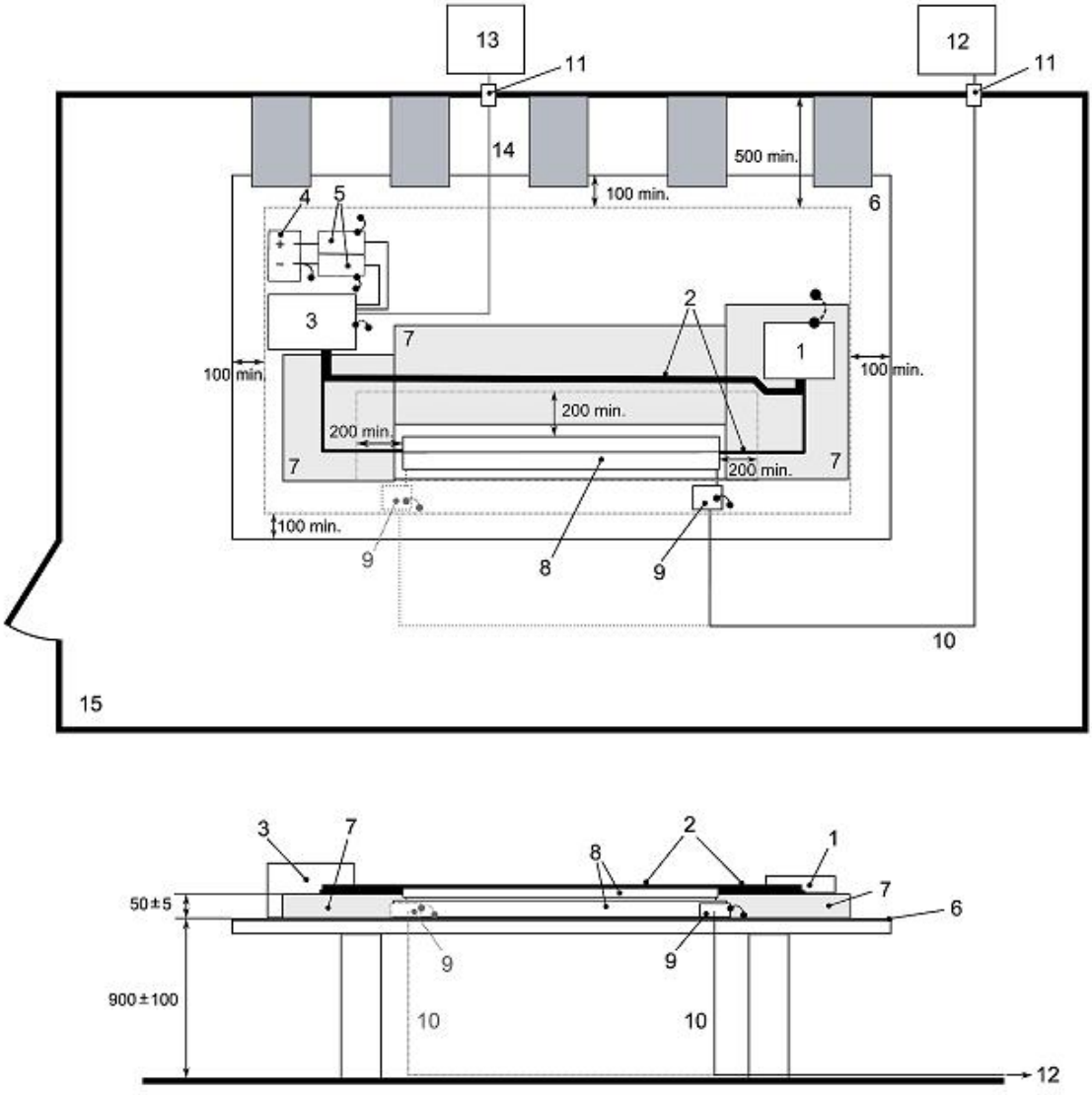
The test setup is shown in figure 3.

The requirements for the measuring equipment (ground plate, voltage supply, artificial network, simulated load) as per CISPR 25 must be met.

The DUT must be situated on a non-conductive rubber pad with low relative permittivity ($\varepsilon_r \leq 1{,}4$) (50 ± 5) mm above the ground plate. The DUT housing must not be connected with the ground plate, unless a simulation of the actual situation in the vehicle is intended. The DUT must be at least 100 mm away from the edge of the ground plate. The test plan must simulate the actual arrangement in the vehicle and must specify whether a distant or local ground is to be used. It must also specify the use of isolating spacers and the electrical connection of the DUT housing with the ground plate.

The test wiring harness must be ($1\,700^{+300}_{-0}$) mm in length (or as agreed in the test plan) and be situated on a non-conductive base with low relative permittivity ($\varepsilon_r \leq 1{,}4$) (50 ± 5) mm above the ground plate. The cables in the test wiring harness that are not in the coupling clamp must be approximately parallel and adjacent, and must have a minimum distance of 200 mm to the septum of the coupling clamp, unless otherwise specified in the test plan. The cables to be measured must be laid flat next to one another and fixed in the coupling clamp. As an alternative, a flat ribbon cable may be used in the coupling clamp with double-sided jack panels. The cover of the coupling clamp must be closed.

All dimensions in mm.



Legend

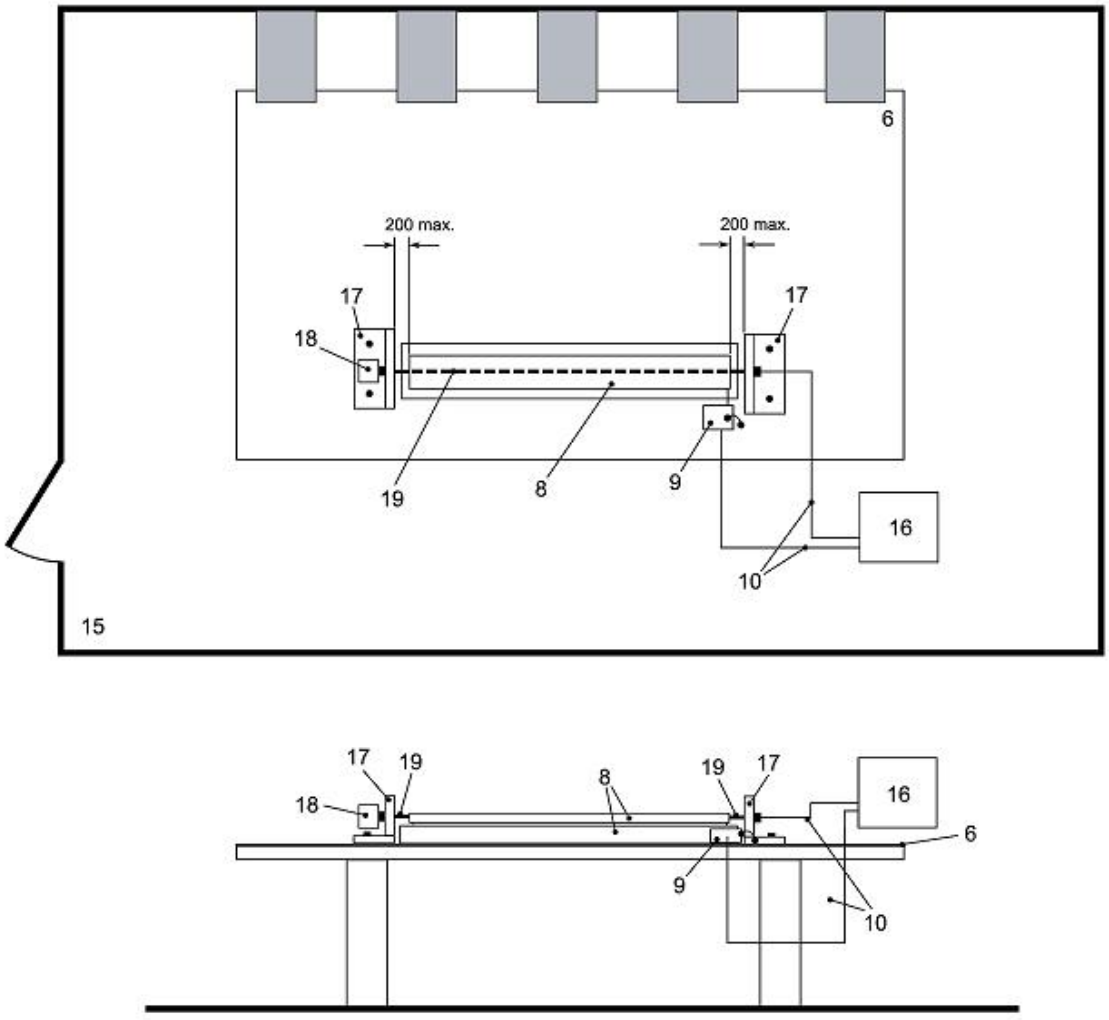
1	DUT (locally connected to ground, if specified in test plan)	9	Impedance adapter
2	Test wiring harness	10	High-quality coaxial cable
3	Load simulation	11	Lead-through connection
4	Voltage supply	12	Measuring receiver
5	Artificial network (AN)	13	Triggering and monitoring system
6	Ground plate (electrically connected with the shielded chamber)	14	Optical fiber
7	Base with low relative permittivity ($\varepsilon_r \leq 1,4$)	15	Shielded enclosure
8	Coupling clamp (CCC)		

Figure 3 – CCC test setup (CV test)

5.5.2 System insertion loss (IL)

The system IL of the test setup must be measured as per figure 4.

All dimensions in mm.



Legend

6	Ground plate (electrically connected with the shielded chamber)	16	Measuring device
		17	Reference cable adapter
8	Coupling clamp (CCC)	18	Coaxial 50 Ω terminal resistance
9	Impedance adapter	19	Reference cable
10	High-quality coaxial cables		
15	Shielded enclosure		

Figure 4 – CCC measurement of the system IL (CV test)

A network analyzer (scalar or vectorial), a measurement receiver with an integrated tracking generator, or a measurement receiver and a separate 50 Ω signal generator may be used to measure the system IL.

A reference cable with an internal conductor and a dielectric with the following technical data must be used:

– Inside diameter: 0,48 mm
– Outer diameter: 1,48 mm
– Material of the dielectric PE

NOTE 1 The technical data of the reference cable are the data of the internal conductor of the dielectric from an RG174. A reference cable can be prepared by removing the outer cable sleeve and the outer conductor from an RG174.

The reference cable adapters must be stable metal brackets with a coaxial socket connector (e.g., N, BNC, SMA). They must be bolted on the ground plate or pressed with a screw clamp on the ground plate, in order to ensure a low-impedance connection. The central wires of the coaxial socket connectors must be mounted at the level of the cables in the septum of the capacitive coupling clamp.

The capacitive coupling clamp and the impedance adapter must be placed in the same manner as in the test setup and fastened. The measurement of the system IL must be conducted inclusive of the optional capacitors for sensitivity reduction.

The distances between reference cable adapters and the septum of the capacitive coupling clamp must not exceed 200 mm.

The length of the reference cable must be selected such that it lies directly in the septum, preferably slightly taut.

The signal is fed in on the DUT side via the reference cable adapter into the reference cable.

To determine the system insertion loss, measure the output signal on the DUT side of the capacitive coupling clamp; that is, measure the system insertion loss as near-end crosstalk (NEXT).

The system IL in dB results from the following:

$$A_{CCC} = -20 \times \log_{10}(S_{21}) \quad (2)$$

Examine the overloading behavior of the measuring system by interposing a 50 Ω HF amplifier between the network analyzer or tracking/signal generator and the reference cable adapter. Using a 50 Ω HF amplifier with at least 10 W rated output power to boost the input signal in the reference cable, it can be verified that the 1 dB compression point is at least 15 V.

5.5.3 Technical requirements for the test setup

The inherent noise of the test setup corrected by the system IL must be at least 6 dB less than the limits to be verified.

The 1 dB compression point must not be exceeded with a sinusoidal signal on the reference cable of 15 V amplitude.

NOTE 2 The dynamic range of the antenna impedance converter used can be exploited through the use of suitable, optional capacitors to ground and/or in series circuit at the input of the AM antenna impedance converter (typical values between 1 pF and 3 nF).

5.5.4 Test conditions

The standard test conditions must be used as per section 3.3 of this TL.

If a DUT has more than 20 cables, these must be divided into groups with up to 20 cables each. The power supply cables of the DUT must be integrated into one group if possible. The cable distribution into groups must be defined in the test plan. Each group must be tested individually.

The group(s) that contain(s) the power supply cables must be measured in two configurations:

– All cables of the group except the DUT supply lines must be laid in the capacitive coupling clamp.
– All cables of the group including the DUT supply lines must be laid in the capacitive coupling clamp.

The interference voltage is measured at the capacitive coupling clamp via the impedance adapter.

Two measurements are required: one on the side of the DUT and one on the side of the periphery and load simulation. The basis here are the distinctions between near-end crosstalk (NEXT) and far-end crosstalk (FEXT). Both measurements must comply with the limits as per table 8.

5.5.5 Requirements

All emission limits must be adhered to for the bands defined in table 8.

Table 8 – Measurement receiver settings and limits (CV test)

Test no.:	Service or band	Frequency	PK				QP				AV			
			Limit			BW	Limit			BW	Limit			BW
		f in MHz	U/dB (µV) Class			f in kHz	U/dB (µV) Class			f in kHz	U/dB (µV) Class			f in kHz
			3	4	5		3	4	5		3	4	5	
Base limits														
B1		0,28 ... 0,52	91 - 59,51 × lg(f/0,28)[a]			9/10	-			-	81 - 59,51 × lg(f/0,28)[a]			9/10
B2		0,52 ... 30	75			9/10	-			-	65			9/10
Broadcast														
1[b]	LW	0,15 ... 0,28	-			-	77	67	**57**	9/10	70	60	**50**	9/10
2	MW	0,52 ... 1,73	-			-	57	49	**41**	9/10	50	42	**34**	9/10
3[b]	SW 75 m	3,85 ... 4,0	-			-	52	46	**40**	9/10	45	39	**33**	9/10
4[b]	SW 49 m	5,8 ... 6,3	-			-	52	46	**40**	9/10	45	39	**33**	9/10
5[b]	SW 41 m	7,1 ... 7,6	-			-	52	46	**40**	9/10	45	39	**33**	9/10
6[b]	SW 31 m	9,3 ... 10,0	-			-	52	46	**40**	9/10	45	39	**33**	9/10
7[b]	SW 25 m	11,5 ... 12,1	-			-	52	46	**40**	9/10	45	39	**33**	9/10
8	NFC SW 22 m	13,5 ... 13,9	-			-	52	46	**40**	9/10	45	39	**33**	9/10
9[b]	SW 19 m	15,0 ... 15,8	-			-	52	46	**40**	9/10	45	39	**33**	9/10
10[b]	SW 16 m	17,4 ... 17,9	-			-	52	46	**40**	9/10	45	39	**33**	9/10
11[b]	SW 15 m	18,9 ... 19,1	-			-	52	46	**40**	9/10	45	39	**33**	9/10
12[b]	SW 13 m	21,4 ... 21,9	-			-	52	46	**40**	9/10	45	39	**33**	9/10

Test no.:	Service or band	Frequency	PK				QP				AV			
			Limit			BW	Limit			BW	Limit			BW
		f in MHz	U/dB (µV)			f in kHz	U/dB (µV)			f in kHz	U/dB (µV)			f in kHz
			Class				Class				Class			
			3	4	5		3	4	5		3	4	5	
13[b)]	SW 11 m	25,6 ... 26,1	-			-	52	46	**40**	9/10	45	39	**33**	9/10
Mobile and other services														
22	125 kHz	0,1 ... 0,15	93	83	**73**	9/10	-			-	-			-
23[c)]	CB radio	26,5 ... 29,7	75	69	**63**	9/10	-			-	63	53	**43**	9/10
In principle, measurements may be conducted with the peak detector in all ranges. If the peak measured value lies below the quasi-peak limit, the quasi-peak limit is fulfilled.														
Limit class 3 must be selected for short-term interferers (e.g., adjusting motors) under consideration of section 2.1 and section 5.2 "Limit classes".														
For interferences that can be attributed to brush sparking (commutator interferers), the high-voltage ignition system, and timed injection systems (diesel engines, Otto engines), limit class 3 may be selected for the MW range when measuring with the quasi-peak detector under consideration of section 5.2 "Limit classes". The average limit must be complied with unchanged.														

a) In the formulae, the frequency f must be entered in MHz; "lg" denominates the logarithm to the base 10.

b) The requirement applies only to the IBK component

c) The main area of application is in heavy commercial vehicles.

5.6 HF emissions – measurements with the clamp-on current probe (CP test, optional)

The HF currents must be measured on all cables except the supply lines as per CISPR 25.

5.6.1 Test setup

The test setup is described in CISPR 25.

5.6.2 Test conditions

The test conditions as per section 3.3 must be applied. All connecting lines except the supply lines must be placed in the clamp-on current probe.

5.6.3 Requirements

All emission limits must be adhered to for the bands defined in table 9.

Table 9 – Measurement receiver settings and limits (CP test)

Test no.:	Service or band	Frequency	PK				QP				AV			
			Limit			BW	Limit			BW	Limit			BW
		f in MHz	I/dB (µA)			f in kHz	I/dB (µA)			f in kHz	I/dB (µA)			f in kHz
			Class				Class				Class			
			3	4	5		3	4	5		3	4	5	
Base limits														
B11		30 ... 108	**28**			120	-			-	**18**			120

Test no.:	Service or band	Frequency	PK				QP				AV			
			Limit			BW	Limit			BW	Limit			BW
		f in MHz	l/dB (µA)			f in kHz	l/dB (µA)			f in kHz	l/dB (µA)			f in kHz
			Class				Class				Class			
			3	4	5		3	4	5		3	4	5	
Broadcast														
14	VHF	76 ... 108	-			-	-3	-9	**-15**	120	-10	-16	**-22**	120
Broadcast – digital														
18[a)]	TV I	54 ... 88	26	20	**14**	1 000	-			-	11	5	**-1**	1 000
19	TV II	90 ... 108	21	16	**9**	1 000	-			-	6	0	**-6**	1 000
Mobile and other services														
25	4 m/ BOS	84,015 ... 87,255	19	13	**7**	120	-			-	-14	-20	**-26**	9/10
In principle, measurements may be conducted with the peak detector in all ranges. If the peak measured value lies below the quasi-peak limit, the quasi-peak limit is fulfilled.														
Limit class 3 may be selected for short-term interferers (e.g., adjusting motors) under consideration of section 2.1 and section 5.2 "Limit classes".														

a) The requirement applies only to the IBK component

5.7 HF emissions – measurements with the TEM cell (TEM test, optional)

The HF emissions must be measured with the TEM cell as per CISPR 25.

5.7.1 Test setup

The test setup is described in CISPR 25.

5.7.2 Test conditions

The test conditions as per section 3.3 must be applied.

5.7.3 Requirements

All emission limits must be adhered to for the bands defined in table 10.

Table 10 – Measurement receiver settings and limits (TEM test)

Test no.:	Service or band	Frequency	PK				QP				AV			
			Limit			BW	Limit			BW	Limit			BW
		f in MHz	U/dB (µV)			f in kHz	U/dB (µV)			f in kHz	U/dB (µV)			f in kHz
			Class				Class				Class			
			3	4	5		3	4	5		3	4	5	
Base limits														
B12		0,28 ... 30	**40**			9/10	-			-	**30**			9/10
B13		30 ... 230	**50**			120	-			-	**40**			120
Broadcast														

Test no.:	Service or band	Frequency	PK				QP				AV			
			Limit			BW	Limit			BW	Limit			BW
		f in MHz	U/dB (µV)			f in kHz	U/dB (µV)			f in kHz	U/dB (µV)			f in kHz
			Class				Class				Class			
			3	4	5		3	4	5		3	4	5	
1[a)]	LW	0,15 ... 0,28	-			-	30	20	**10**	9/10	23	13	**3**	9/10
2	MW	0,52 ... 1,73	-			-	23	15	**7**	9/10	16	8	**0**	9/10
3[a)]	SW 75 m	3,85 ... 4,0	-			-	19	13	**7**	9/10	12	6	**0**	9/10
4[a)]	SW 49 m	5,8 ... 6,3	-			-	19	13	**7**	9/10	12	6	**0**	9/10
5[a)]	SW 41 m	7,1 ... 7,6	-			-	19	13	**7**	9/10	12	6	**0**	9/10
6[a)]	SW 31 m	9,3 ... 10,0	-			-	19	13	**7**	9/10	12	6	**0**	9/10
7[a)]	SW 25 m	11,5 ... 12,1	-			-	19	13	**7**	9/10	12	6	**0**	9/10
8	NFC SW 22 m	13,5 ... 13,9	-			-	19	13	**7**	9/10	12	6	**0**	9/10
9[a)]	SW 19 m	15,0 ... 15,8	-			-	19	13	**7**	9/10	12	6	**0**	9/10
10[a)]	SW 16 m	17,4 ... 17,9	-			-	19	13	**7**	9/10	12	6	**0**	9/10
11[a)]	SW 15 m	18,9 ... 19,1	-			-	19	13	**7**	9/10	12	6	**0**	9/10
12[a)]	SW 13 m	21,4 ... 21,9	-			-	19	13	**7**	9/10	12	6	**0**	9/10
13[a)]	SW 11 m	25,6 ... 26,1	-			-	19	13	**7**	9/10	12	6	**0**	9/10
14	VHF	76 ... 108	-			-	19	13	**7**	120	12	6	**0**	120
Broadcast – digital														
15	DAB	174 ... 241	32	26	**20**	1 000	-			-	22	16	**10**	1 000
18[a)]	TV I	54 ... 88	42	36	**30**	1 000	-			-	27	21	**15**	1 000
19	TV II	90 ... 108	37	31	**25**	1 000	-			-	22	16	**10**	1 000
20	TV III	170 ... 230	37	31	**25**	1 000	-			-	22	16	**10**	1 000
Mobile and other services														
22	125 kHz	0,1 ... 0,15	35	29	**23**	9/10	-			-	-			-
23[b)]	CB radio	26,5 ... 29,7	42	36	**30**	9/10	-			-	22	16	**10**	9/10
24	4 m/ BOS	84,015 ... 87,255	35	29	**23**	120	-			-	2	-4	**-10**	9/10
25	2 m/ taxi	147 ... 164	35	29	**23**	120	-			-	2	-4	**-10**	9/10
26	2 m/ BOS	167,56 ... 169,38	35	29	**23**	120	-			-	2	-4	**-10**	9/10
27	2 m/ BOS	172,16 ... 173,98	35	29	**23**	120	-			-	2	-4	**-10**	9/10
In principle, measurements may be conducted with the peak detector in all ranges. If the peak measured value lies below the quasi-peak limit, the quasi-peak limit is fulfilled.														

Test no.:	Service or band	Frequency	PK				QP				AV			
			Limit			BW	Limit			BW	Limit			BW
		f in MHz	U/dB (µV)			f in kHz	U/dB (µV)			f in kHz	U/dB (µV)			f in kHz
			Class				Class				Class			
			3	4	5		3	4	5		3	4	5	
Limit class 3 may be selected for short-term interferers (e.g., adjusting motors) under consideration of section 2.1 and section 5.2 "Limit classes".														
For interferences that can be attributed to brush sparking (commutator interferers), the high-voltage ignition system, and timed injection systems (diesel engines, Otto engines), limit class 3 may be selected for the MW range when measuring with the quasi-peak detector under consideration of section 5.2 "Limit classes". The average limit must be complied with unchanged.														

a) The requirement applies only to the IBK component

b) The main area of application is in heavy commercial vehicles.

5.8 HF emissions – measurements with the stripline (SL test, optional)

The HF emissions must be measured with the stripline as per CISPR 25.

5.8.1 Test setup

The test setup is described in CISPR 25.

Deviating therefrom, a cable length of (1 500 ± 10) mm may be used parallel to the septum after agreement.

5.8.2 Test conditions

The standard test conditions as per section 3.3 must be applied.

5.8.3 Requirements

All emission limits must be adhered to for the bands defined in table 11.

The limits shown in table 11 apply to a 90 Ω stripline. The following formula (3) can be used to convert the limits to striplines with different wave impedances:

Formula to convert limits

$$K90\ \Omega / Z2 = 20\log\sqrt{90\ \Omega / Z2} \qquad (3)$$

Table 11 – Measurement receiver settings and limits for the 90 Ω stripline (SL test)

Test no.:	Service or band	Frequency	PK				QP				AV			
			Limit			BW	Limit			BW	Limit			BW
		f in MHz	U/dB (µV)			f in kHz	U/dB (µV)			f in kHz	U/dB (µV)			f in kHz
			Class				Class				Class			
			3	4	5		3	4	5		3	4	5	
Base limits														
B14		0,28 ... 30	61			9/10	-			-	51			9/10
B15		30 ... 960	71			120	-			-	61			120

Test no.:	Service or band	Frequency	PK				QP				AV			
			Limit			BW	Limit			BW	Limit			BW
		f in MHz	U/dB (µV)			f in kHz	U/dB (µV)			f in kHz	U/dB (µV)			f in kHz
			Class				Class				Class			
			3	4	5		3	4	5		3	4	5	
Broadcast														
1[a)]	LW	0,15 ... 0,28	-			-	51	41	**31**	9/10	44	34	**24**	9/10
2	MW	0,52 ... 1,73	-			-	44	36	**28**	9/10	37	29	**21**	9/10
3[a)]	SW 75 m	3,85 ... 4,0	-			-	40	34	**28**	9/10	33	27	**21**	9/10
4[a)]	SW 49 m	5,8 ... 6,3	-			-	40	34	**28**	9/10	33	27	**21**	9/10
5[a)]	SW 41 m	7,1 ... 7,6	-			-	40	34	**28**	9/10	33	27	**21**	9/10
6[a)]	SW 31 m	9,3 ... 10,0	-			-	40	34	**28**	9/10	33	27	**21**	9/10
7[a)]	SW 25 m	11,5 ... 12,1	-			-	40	34	**28**	9/10	33	27	**21**	9/10
8	NFC SW 22 m	13,5 ... 13,9	-			-	40	34	**28**	9/10	33	27	**21**	9/10
9[a)]	SW 19 m	15,0 ... 15,8	-			-	40	34	**28**	9/10	33	27	**21**	9/10
10[a)]	SW 16 m	17,4 ... 17,9	-			-	40	34	**28**	9/10	33	27	**21**	9/10
11[a)]	SW 15 m	18,9 ... 19,1	-			-	40	34	**28**	9/10	33	27	**21**	9/10
12[a)]	SW 13 m	21,4 ... 21,9	-			-	40	34	**28**	9/10	33	27	**21**	9/10
13[a)]	SW 11 m	25,6 ... 26,1	-			-	40	34	**28**	9/10	33	27	**21**	9/10
14	VHF	76 ... 108	-			-	25	19	**13**	120	18	12	**6**	120
Broadcast – digital														
15	DAB	174 ... 241	38	32	**26**	1 000	-			-	28	22	**16**	1 000
18[a)]	TV I	54 ... 88	48	42	**36**	1 000	-			-	33	27	**21**	1 000
19	TV II	90 ... 108	43	37	**31**	1 000	-			-	28	22	**16**	1 000
20	TV III	170 ... 230	43	37	**31**	1 000	-			-	28	22	**16**	1 000
21	TV IV/V	470 ... 806	43	37	**31**	1 000	-			-	28	22	**16**	1 000
Mobile and other services														
22	125 kHz	0,1 ... 0,15	64	54	**44**	9/10	-			-	-			-
23[b)]	CB radio	26,5 ... 29,7	63	57	**51**	9/10	-			-	43	37	**31**	9/10
24	4 m/ BOS	84,015 ... 87,255	41	35	**29**	120	-			-	8	2	**-4**	9/10
25	2 m/ taxi	147 ... 164	41	35	**29**	120	-			-	8	2	**-4**	9/10
26	2 m/ BOS	167,56 ... 169,38	41	35	**29**	120	-			-	8	2	**-4**	9/10
27	2 m/ BOS	172,16 ... 173,98	41	35	**29**	120	-			-	8	2	**-4**	9/10
28	SRD	313 ... 317	27	21	**15**	9/10	-			-	7	1	**-5**	9/10
29	Trunked radio	390 ... 400	38	32	**26**	120	-			-	18	12	**6**	120

Test no.:	Service or band	Frequency	PK				QP				AV			
			Limit			BW	Limit			BW	Limit			BW
		f in MHz	U/dB (µV)			f in kHz	U/dB (µV)			f in kHz	U/dB (µV)			f in kHz
			Class				Class				Class			
			3	4	5		3	4	5		3	4	5	
30	Trunked radio	420 ... 430	38	32	**26**	120	-			-	18	12	**6**	120
31	SRD	433 ... 435	27	21	**15**	9/10	-			-	7	1	**-5**	9/10
32	Trunked radio	460 ... 470	38	32	**26**	120	-			-	18	12	**6**	120
33	LTE	791 ... 821	48	42	**36**	1 000	-			-	28	22	**16**	1 000
34	PDC, D-AMPS	851 ... 894	44	38	**32**	120	-			-	24	18	**12**	120
35	SRD	868 ... 876	33	27	**21**	9/10	-			-	13	7	**1**	9/10
36	GSM-900	925 ... 960	44	38	**32**	120	-			-	24	18	**12**	120
In principle, measurements may be conducted with the peak detector in all ranges. If the peak measured value lies below the quasi-peak limit, the quasi-peak limit is fulfilled.														
Limit class 3 may be selected for short-term interferers (e.g., adjusting motors) under consideration of section 2.1 and section 5.2 "Limit classes".														
For interferences that can be attributed to brush sparking (commutator interferers), the high-voltage ignition system, and timed injection systems (diesel engines, Otto engines), limit class 3 may be selected for the MW range when measuring with the quasi-peak detector under consideration of section 5.2 "Limit classes". The average limit must be complied with unchanged.														

a) The requirement applies only to the IBK component

b) The main area of application is in heavy commercial vehicles.

6 Applicable documents

The following documents cited in this Standard are necessary to its application.

Some of the cited documents are translations from the German original. The translations of German terms in such documents may differ from those used in this Standard, resulting in terminological inconsistency.

Standards whose titles are given in German may be available only in German. Editions in other languages may be available from the institution issuing the standard.

CISPR 16-1-1	Specification for radio-disturbance and immunity-measuring apparatus and methods – part 1-1: radio-disturbance and immunity-measuring apparatus – measuring apparatus
CISPR 25	"Vehicles, boats and internal combustion engines – radio disturbance characteristics – limits and methods of measurement for the protection of on-board receivers"
ISO 7637-3	Road vehicles - Electrical disturbances from conduction and coupling - Part 3: Electrical transient transmission by capacitive and inductive coupling via lines other than supply lines

7 Bibliography

[1] ECE-R 10 "Regulation no. 10 of the United Nations Economic Commission for Europe (UN/ECE) — Uniform provisions concerning the approval of vehicles with regard to electromagnetic compatibility"

Appendix A (normative)

A.1 Measurements in the AM range

For vehicle measuring in the MW range, an impedance adapter (dummy) with high input impedance must be used, depending on the antenna/radio impedance (e.g., type 152-4107, BR2 from TRAWID or EZ12 from R&S, or similar).

The output impedance of the impedance adapter must be 50 Ω. In order to avoid interferences coupled into the measuring receiver by external sources, the following boundary conditions must be taken into consideration:

- The impedance adapter must be powered internally using batteries and must be placed inside the vehicle so that it is insulated from the vehicle's body.
- The ground connection of the impedance adapter (housing) must be connected to the radio connector (T.31) of the original vehicle wire assembly, with low impedance and a maximum length of 200 mm. See also figure 1.
- In cases where the impedance adapter is to be powered by the electric system, an input filter circuit corresponding to the radio must be connected into the dummy's power supply input.
- The measurement receiver must be decoupled from the chamber shield (possibly, rechargeable battery or operation by isolating transformer; do not lay measuring cable shield on the chamber shield or use an optical transmission link). The measuring cable must not exceed 3 000 mm in length and must be provided with ferrites against sheath currents.

NOTE 3 The high-impedance antenna adapter is not needed for vehicles that have antenna systems with 50 Ω output impedance and use only radio devices that have 50 Ω input impedance. Vehicle-specific antenna corrective factors must be observed.

A.2 Subjective evaluation of interference suppression

For a final subjective evaluation of the interference suppression in the free field or in the EMC chamber when feeding in a wanted signal, the following requirements must be fulfilled.

A.2.1 Analog radio and TV ranges and radio applications

For analog radio and TV ranges, the following applies:

The responsible Volkswagen/Audi EMC department determines the minimum number of points to be achieved in the different broadcasting ranges.

For analog radio services, the following applies:

Wanted signals without noise must be interference-free, squelch circuit (set to lowest sensitivity) must not be triggered.

Test procedure:

- Feeding-in of a modulated HF signal via a broadcasting/radio antenna into the EMC chamber with frequencies and modulations as per table A.2 "Settings of HF transmission signals for analog radio frequency ranges"; see table A.1 "Wanted level standard settings".
- Measuring of this HF signal with a measurement receiver and antenna adapter at the end of the antenna cable of the built-in vehicle antenna.

– For radio services, an applicable monopole antenna must be used.
– The measurements are carried out with the average detector and an intermediate frequency bandwidth of 120 kHz in VHF ranges and 9/10 kHz in the MW, 2m, and 4-m ranges (see measuring setup in figure A.1)

The HF generator level must be adjusted such that the following wanted signals are present at the measuring receiver (or car radio):

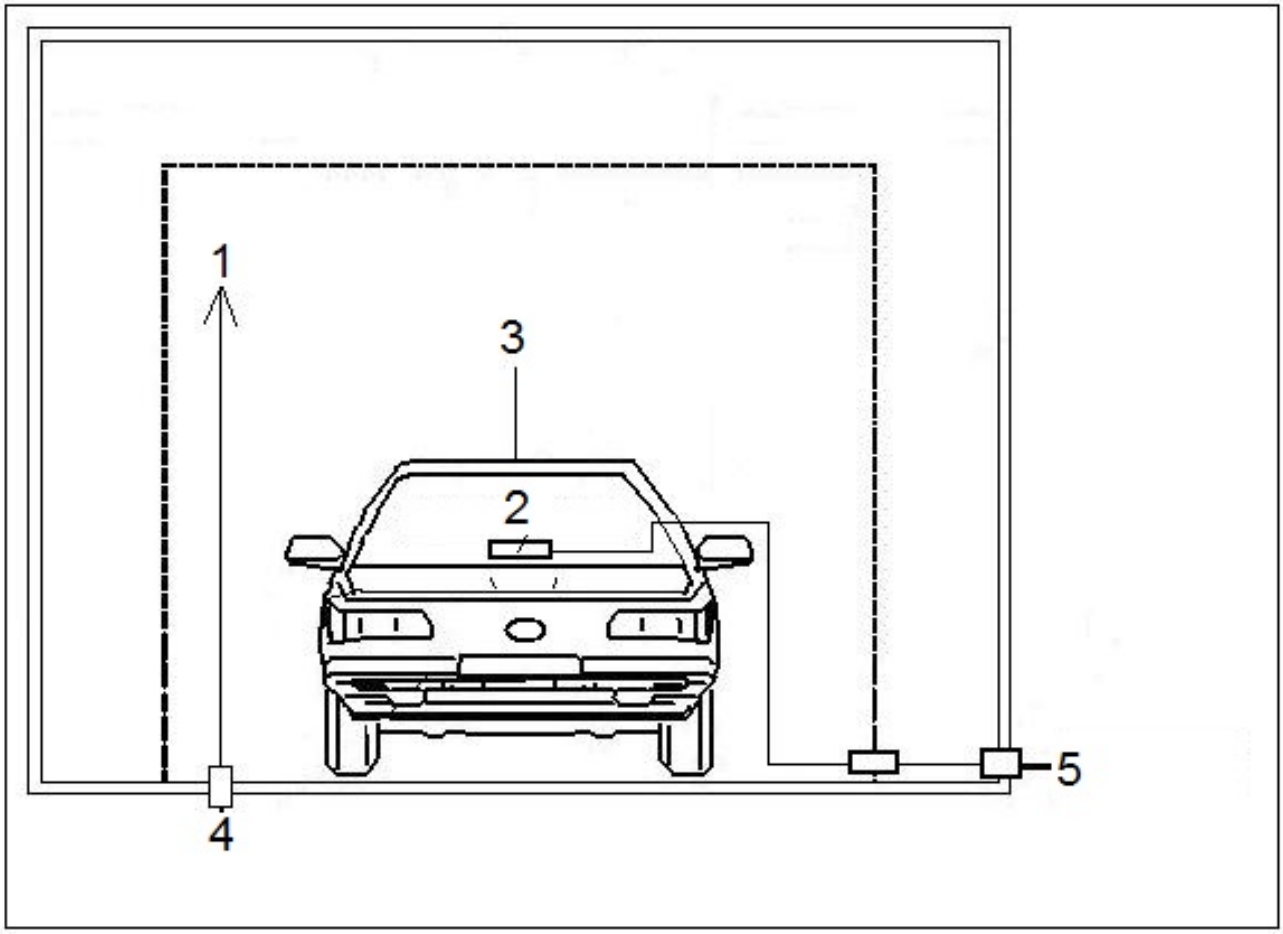
Table A.1 – Wanted level standard settings

LW range	30 dBµV
MW range	15 dBµV (20 dBµV)
VHF range	12 dBµV (20 dBµV)
2-m/4-m band	6 dBµV

NOTE 4 Values in parentheses can be used as an alternative for low-requirement vehicles. This must be determined by the appropriate EMC department at Volkswagen/Audi.

Table A.2 – Settings of HF transmission signals for analog radio frequency ranges

Frequency band	Frequency	Ext. modulation	Mod. rate/degree
MW	Depending on the interference spectrum measured, tests must be conducted in the frequency bands at different frequencies.	Test CD	- / 80%
VHF			75 kHz / -
4m band			2,8 kHz/-
2m band			2,8 kHz/-



Legend

1	Transmitting antenna
2	Radio dummy AM/FM
3	Vehicle antenna
4	Measuring transmitter + CD player
5	Measuring receiver

Figure A.1 – Measuring setup for measuring the wanted signal level for subjective interference suppression evaluation of analog broadcast and radio services

Table A.3 – Evaluation table for subjective interference suppression evaluation of analog broadcast and radio services

Points	Reception	Evaluation
1	**No reception,** no station available, noise	**unacceptable**
2	**A station can be conjectured** noise and interference predominant	**unacceptable**
3	**A station is available** information cannot be clearly recognized	**unacceptable**
4	**Station audible** information recognizable, but the level of interference is annoying	**unacceptable**
5	**Station clearly recognizable** definite degree of interference, but not annoying	**"I would listen if it were important"**
6	**Station has continuous slight interference**	**Usable**
7	**Strong signal, with temporary interference** interference mostly concealed during driving operation	**still good**
8	**Good signal** interferences during driving operation only audible if concentrated on	**good**
9	**Signal without interference** no interference audible during driving operation	**very good**
10	**Signal absolutely free of interference** can be used for stereo even with vehicle standing still, free of noise	**excellent**

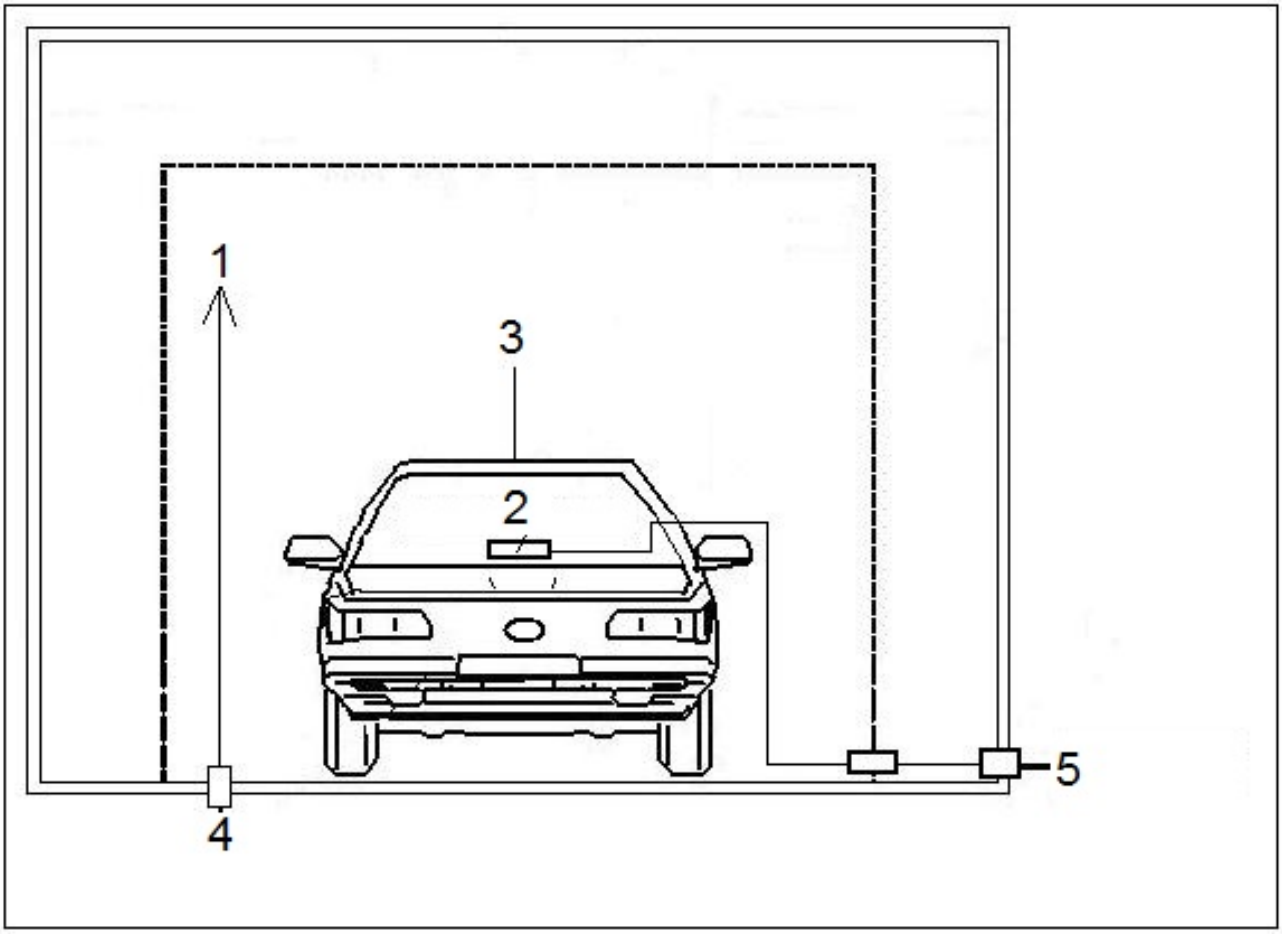
A.2.2 Digital radio and TV ranges (DAB, DVB-T, ...)

Feed-in of an HF signal assigned to the digital service to be tested via a broadcast/radio antenna in the EMC chamber, with settings according to table A.4.

Table A.4 – Settings for HF transmission signal on digital radio and TV

Frequency band	Transmission signal level	Data	Modulation	Parameter
DAB (band III)	Sound stability threshold + 2 dB	MPEG stream (e.g., from R&S SFE Broadcast Tester)	QPSK	–
DAB (band L)	Sound stability threshold + 2 dB		QPSK	–
DVB–T (Europe)[a)]	Sound stability threshold + 2 dB		16 QAM	Carrier: 8k Code rate: 2/3 Guard interval: 1/4
ISDB–T (Japan)	Sound stability threshold + 2 dB		16 QAM	Carrier: 8k Code rate: 2/3 Guard interval: 1/4
DMB–T (China)	Sound stability threshold + 2 dB		16 QAM	–

a) The settings most widely distributed in Europe were selected.
Optional worst-case setting 64 QAM, code rate 2/3, guard interval 1/4



Legend

1 Transmitting antenna
2 Digital receiver
3 Vehicle antenna
4 Digital signal generator
5 Measuring receiver

Figure A.2 – Measuring setup for measuring the wanted signal level for subjective interference suppression evaluation of digital radio and TV services

Definitions:

1. Since in digital radio and TV services, a customer-relevant signal interference is first noticed in the sound, the following definition is made for subjective evaluation:

   The **sound stability threshold** is the point at which, at a level reduction (HF transmission signal level) in 1 dB increments, the first interference with the sound signal is audible.
2. The **test signal transmission level**, which represents a weak station/transmitter, is **2 dB** above the sound stability limit → **test signal transmission level = sound stability threshold level + 2 dB**.

Procedure for setting the transmission signal level and evaluation of the interference potential:

1. Deactivate interfering components. Increase signal level of measurement signal transmitter until interference-free reception is possible.
2. Reduce transmission signal level in 1 dB increments until first interference of sound signal is audible = **sound stability threshold**.
3. Increase transmission signal level by 2 dB = **test signal transmission level**.
4. Activate interfering components.
5. If now an audible interference with the sound signal is present, by slowly increasing or reducing the transmission signal level the transmission level must be determined at which an interference-free reception is just possible = **transmission signal level of the interfered-with station/transmitter**.
6. The difference between the **test signal transmission level** and the **transmission signal level of the interfered-with station/transmitter** is the value for the evaluation criterion.

Table A.5 – Acceptance level for subjective interference suppression evaluation of digital radio and TV services

Difference[a)]	Effect	Evaluation
0 dB	No customer-relevant interference	OK
1 – 2 dB	Reception range reduced	Acceptable
≥ 3 dB	Reduction of reception range that is clearly perceivable for the customer	Not acceptable

a) Difference between transmission signal level of the interfered-with station/transmitter and the test signal transmission level

A.3 Long-distance interference suppression

Measurement of narrowband and broadband radio interferences outside the vehicle intended to protect long-distance reception.

Test procedure and limits as per ECE-R 10 [1]