Introduction of Automobile EMC Standard and TOYO Test System

November 1, 2018

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Overview

Part 1

Movement of international standard ECE R10 for Vehicle and ESA EMC Standards for Vehicles & ESA

Part 2

EMC Test System

Part1 Introduction

- EMC Standards for Vehicles & ESA
- Emission Measurement of ECE R10
- Conducted Emission measurement for "REESS charging mode coupled to the power grid“
  - AC/DC power source
  - Network and Telecommunication

*ESA(Electric Sub Assembly)…In-vehicle equipment
*REESS…Rechargeable Energy Storage System

EMC Standards for Vehicles & ESA

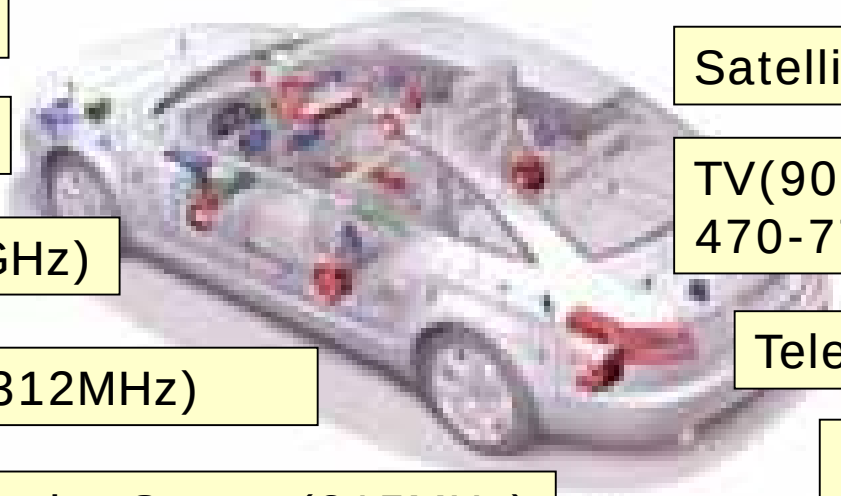
Vehicles are filled with electronic devices

Inside the vehicles are full of electronic devices and noise-sensitive receiving equipment is placed together with powerful transmitting equipment.

VICS(76-90MHz,2.5GHz)

AM,SW,FM(VICS) 522-1629kHz, 2-26MHz,76-90MHz

GPS(1.5GHz)



Satellite Digital Radio(2.6GHz)

ETC(5.8GHz)

TV(90-108MHz,170-220MHz, 470-770MHz)

Bluetooth(2.4GHz)

Telephone(800MHz,1.5GHz)

Keyless entry(312MHz)

Immobilizer(132kHz)

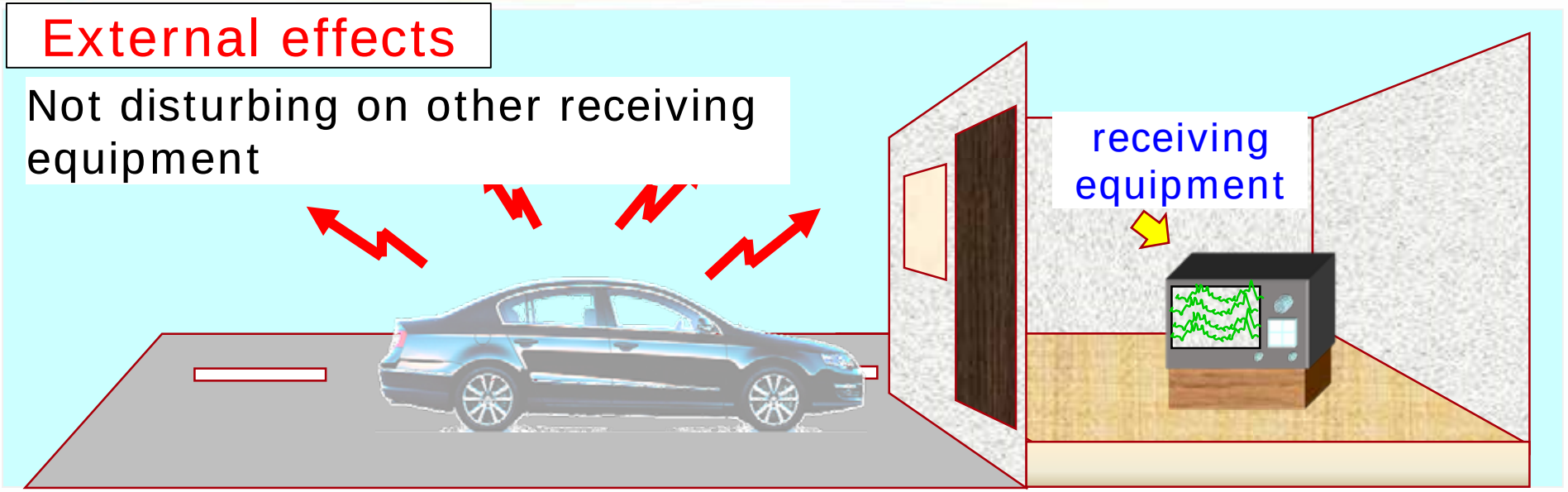
Air pressure for tire Sensor(315MHz)

Sensor : about 60
ECU : about 50(CPU about 150)
Actuator : about 100

What is Required for Vehicles for Radiated Emission

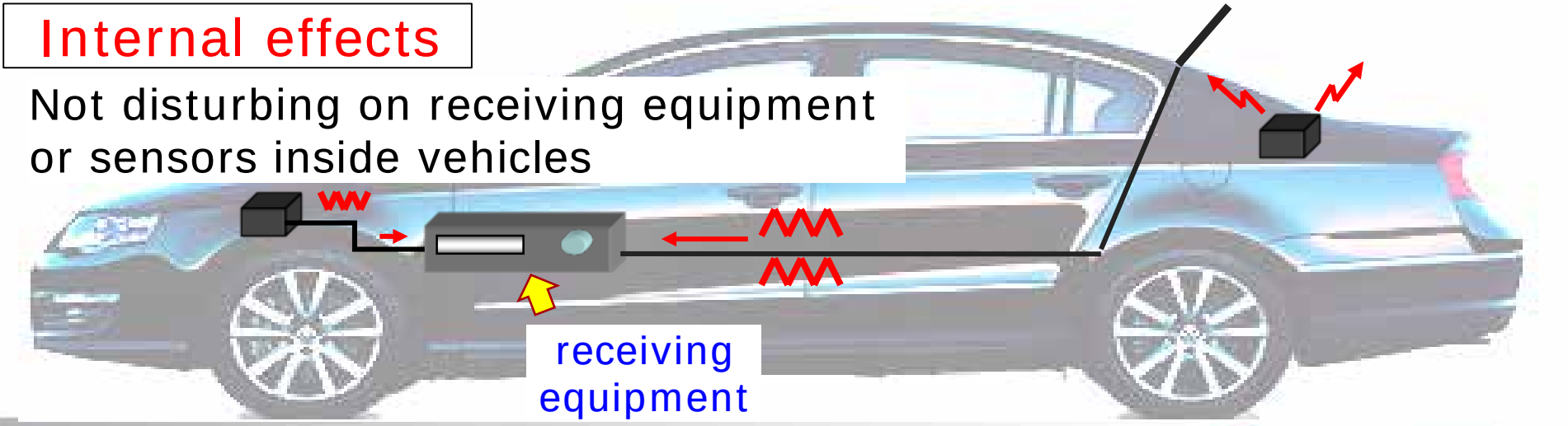
External effects

Not disturbing on other receiving equipment



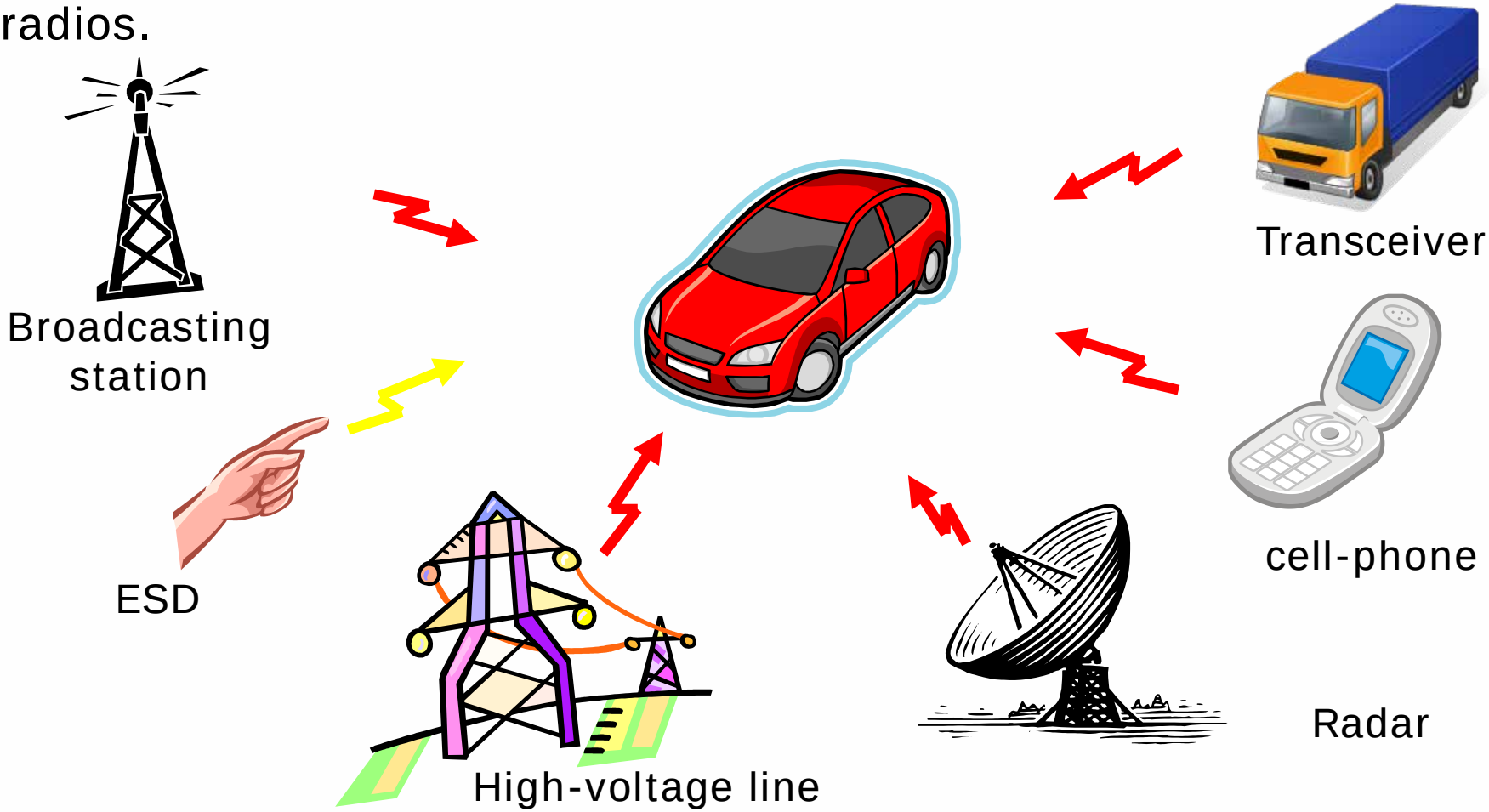
Internal effects

Not disturbing on receiving equipment or sensors inside vehicles



What is Required for Vehicles for radiated Immunity

Capability for electronic systems to work properly in electromagnetic environments induced by broadcast stations or radios.



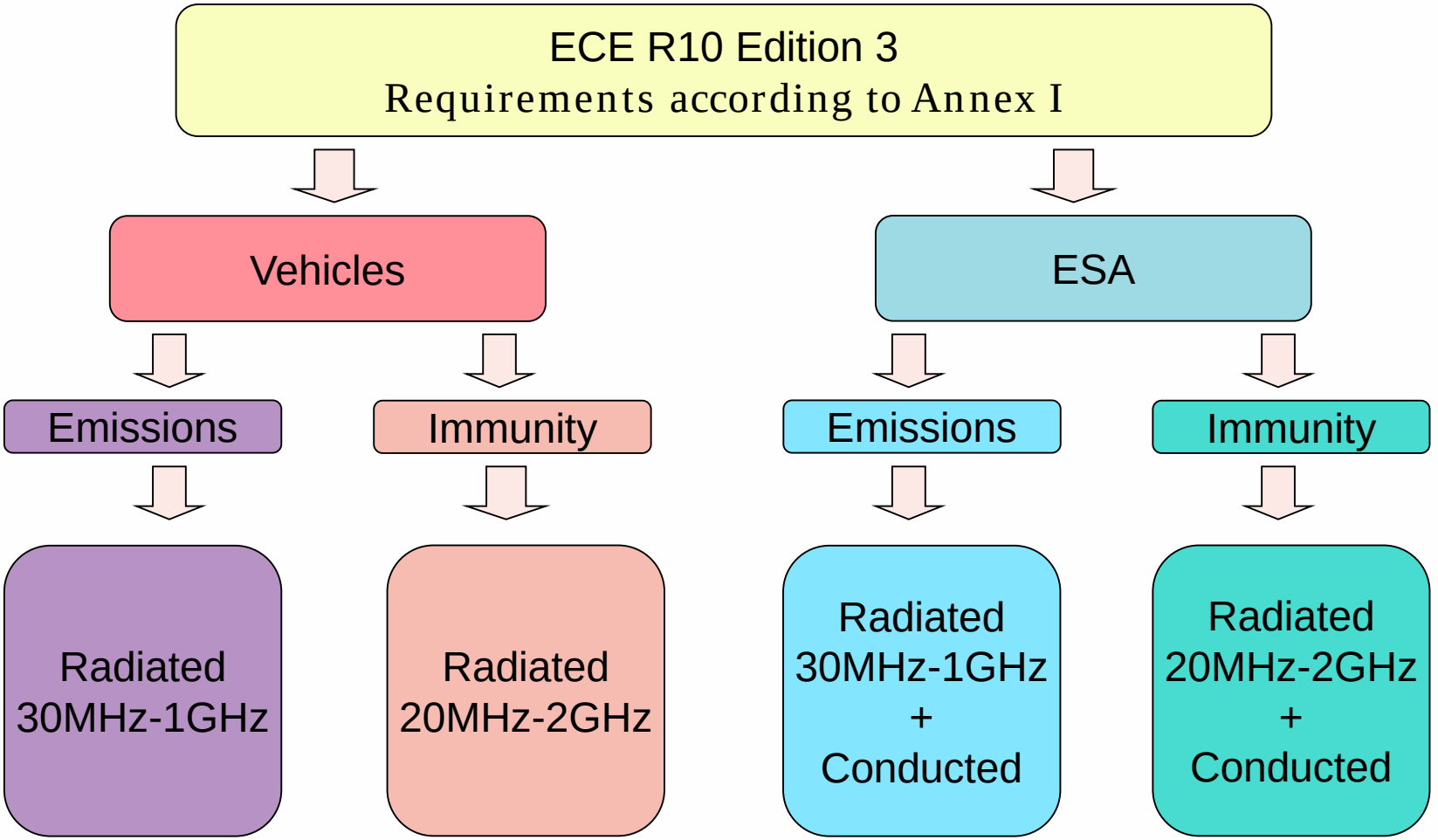
EMC Standards for Vehicles

International Standards	Country Standards	Manufacturer Standards
CISPR(EMI) ISO(EMS) IEC ECE Regulation	EN (2004/104/EC) SAE ECE Regulations etc....	GMW(GM) ES-XW7T (Ford) MBN(Daimler) TSC (TOYOTA) NDS (Nissan) TL(VW) GS(BMW) etc...

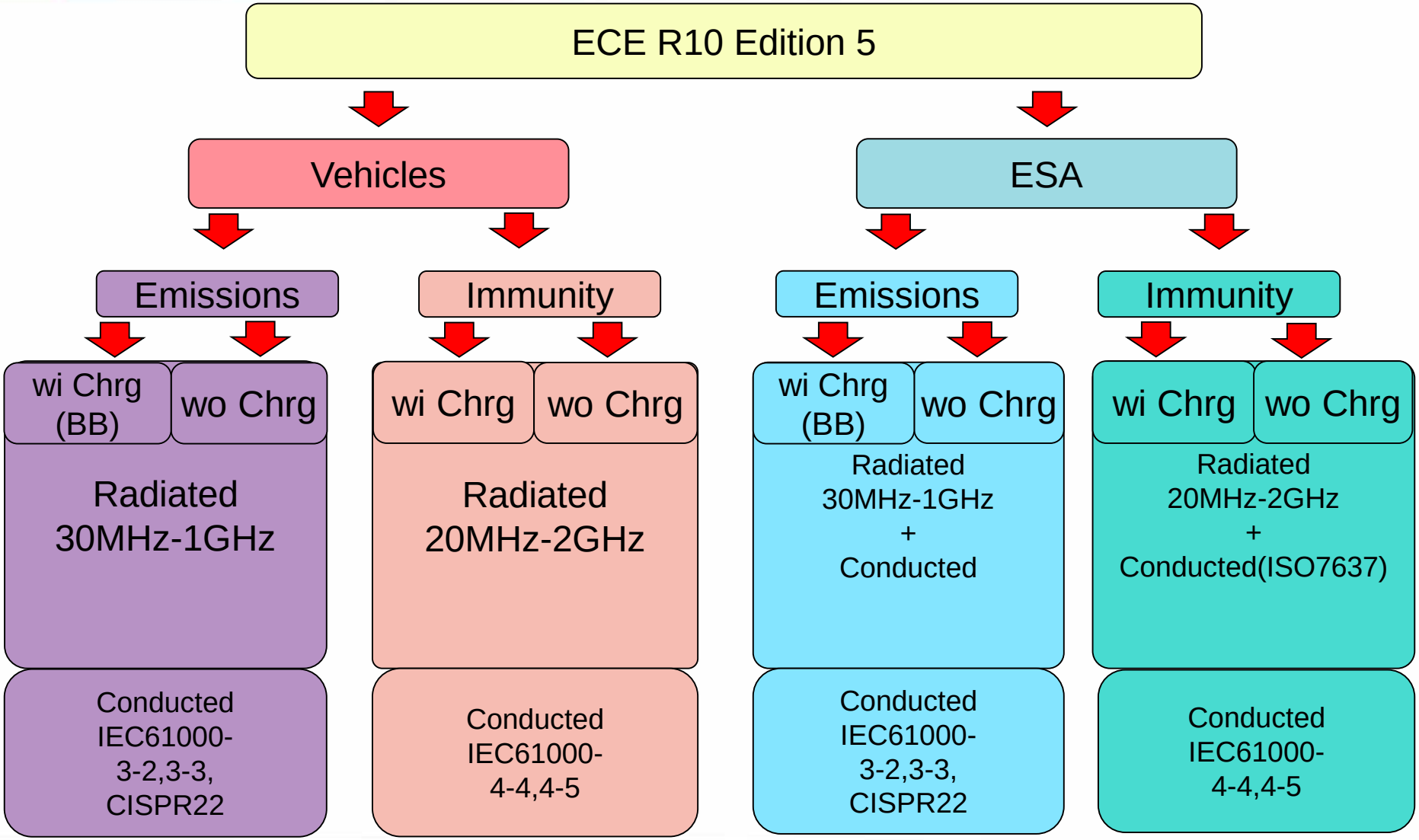
- Even individual countries' and manufacturers' standards instruct that international standards should be referred to in regard to such basics as the test facilities, instruments, and methods used to be used

Emission Measurement of ECE R10

ECE R10 Edition 3
(for conventional vehicle)



ECE R10 Edition 5
(for conventional vehicle + EV + HV)



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EMI test for Vehicle by ECE R10 Edition 5

ECE R10 Edition 5 → Vehicles → Emissions → Radiated 30MHz-1GHz + conducted

Radiated Emissions Test

- Referring CISPR12(2001 Ed.5)
  - Distance 3m or 10m
  - RBW : 120kHz
  - For BB meas. :QP or PK
  - For NB meas. :AV
- Only Broadband test in charge mode

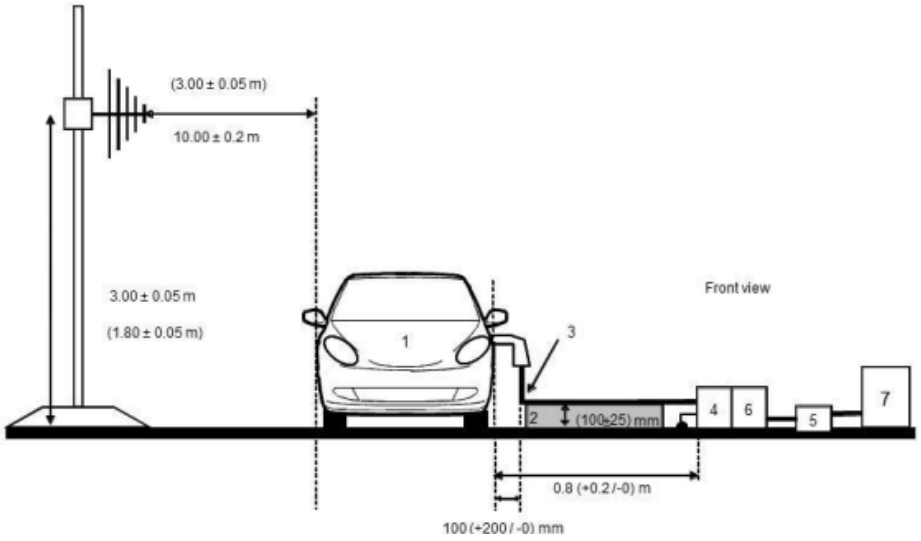
Conducted Emissions Test

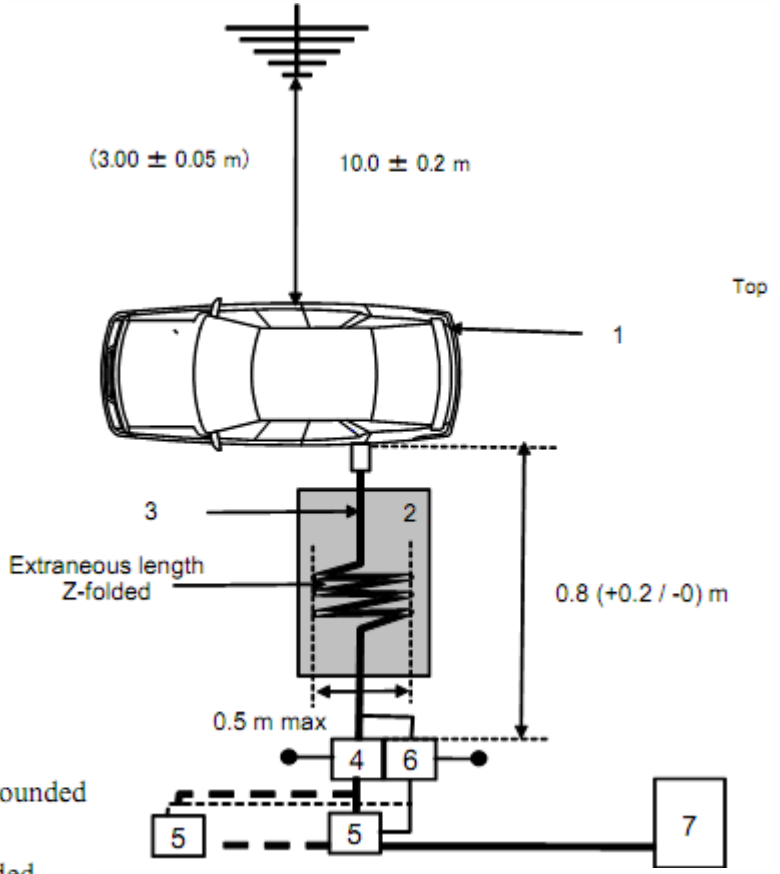
- IEC61000-6-3 (CE for AC)
- CISPR22 (CE for Network)
- IEC61000-3-2,3-3 (harmonics , Voltage change , flicker)

Frequency [MHz]	Broadband Limit [dBuV/m]		Narrowband Limit [dBuV/m]	
	10m	3m	10m	3m
30 - 75	32	42	22	32
75 – 400	32-43	42-53	22-33	32-43
400 – 1000	43	53	33	43

Example of Test setup for radiated emission

Figure 3e





Legend:

1	Vehicle under test
2	Insulating support
3	Charging / communication cable
4	AC or DC artificial network(s) grounded
5	Power mains socket
6	Impedance stabilization(s) grounded
7	Charging station

Vehicle in configuration “REESS charging mode coupled to the power grid”

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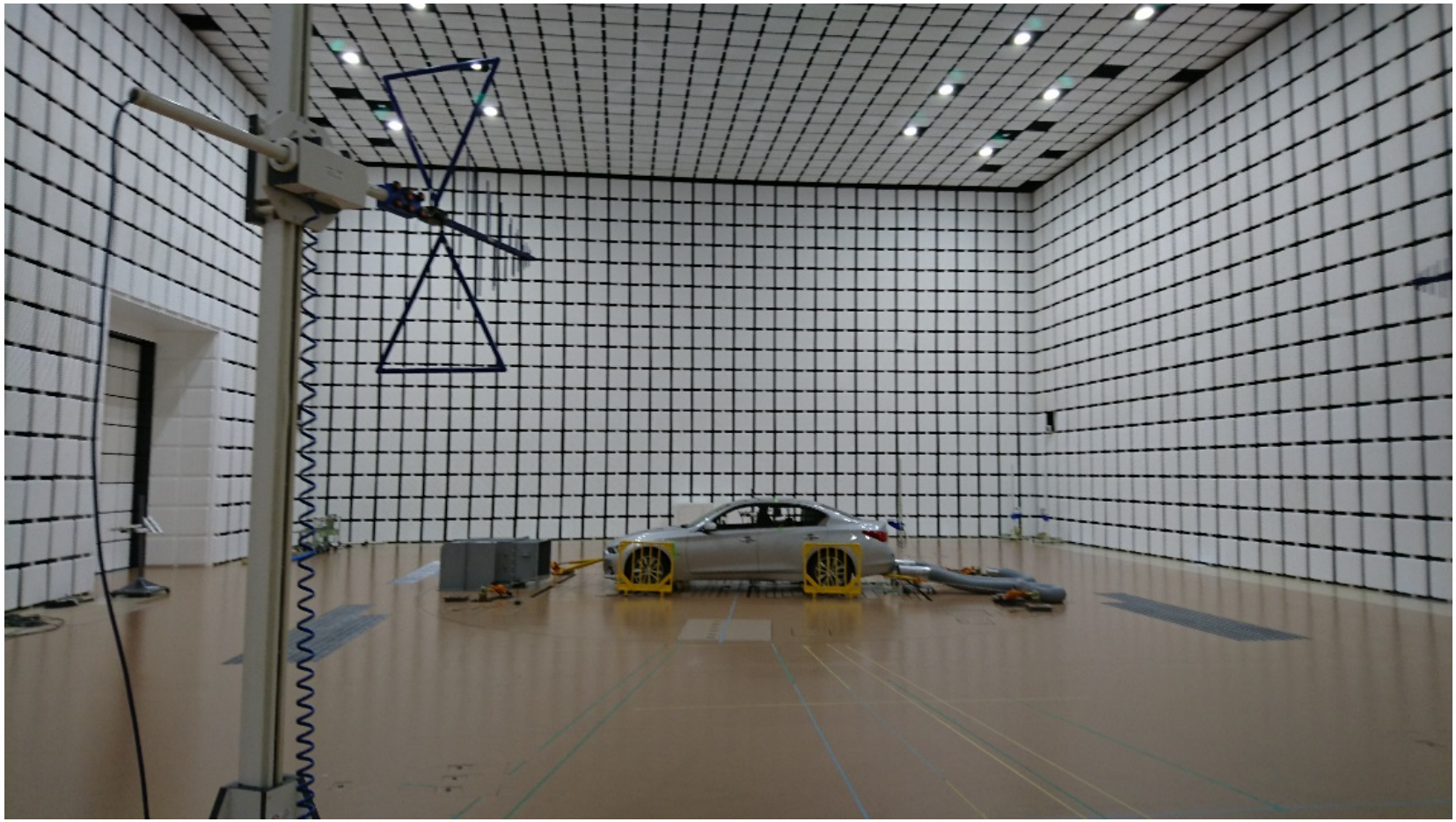
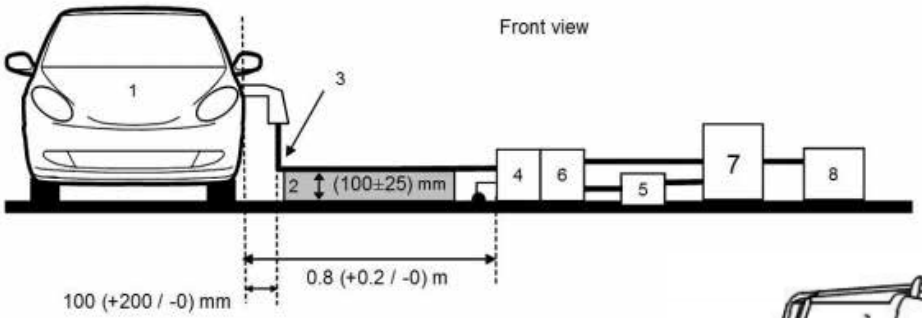
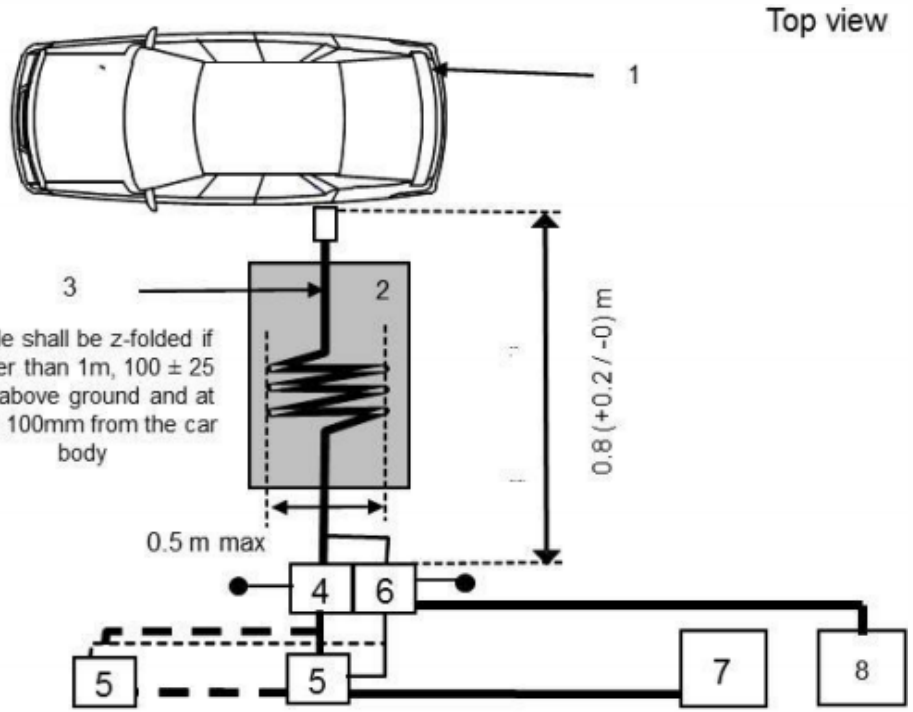
Radiated emission measurement for vehicle



Example of Test setup for conducted emission





Legend:

1 Vehicle under test
2 Insulating support
3 Charging / communication cable
4 AC or DC artificial network(s) grounded (for AC or DC power lines)
5 Power mains socket
6 Impedance stabilization(s) grounded (for communication lines)
7 Charging station
8 Measuring receiver

Vehicle in configuration “REESS charging mode coupled to the power grid”

EMI test for ESA by ECE R10 Edition 5

ECE R10 Edition 5 → ESA → Emissions → Radiated 30MHz-1GHz + Conducted

Radiated Emissions Test

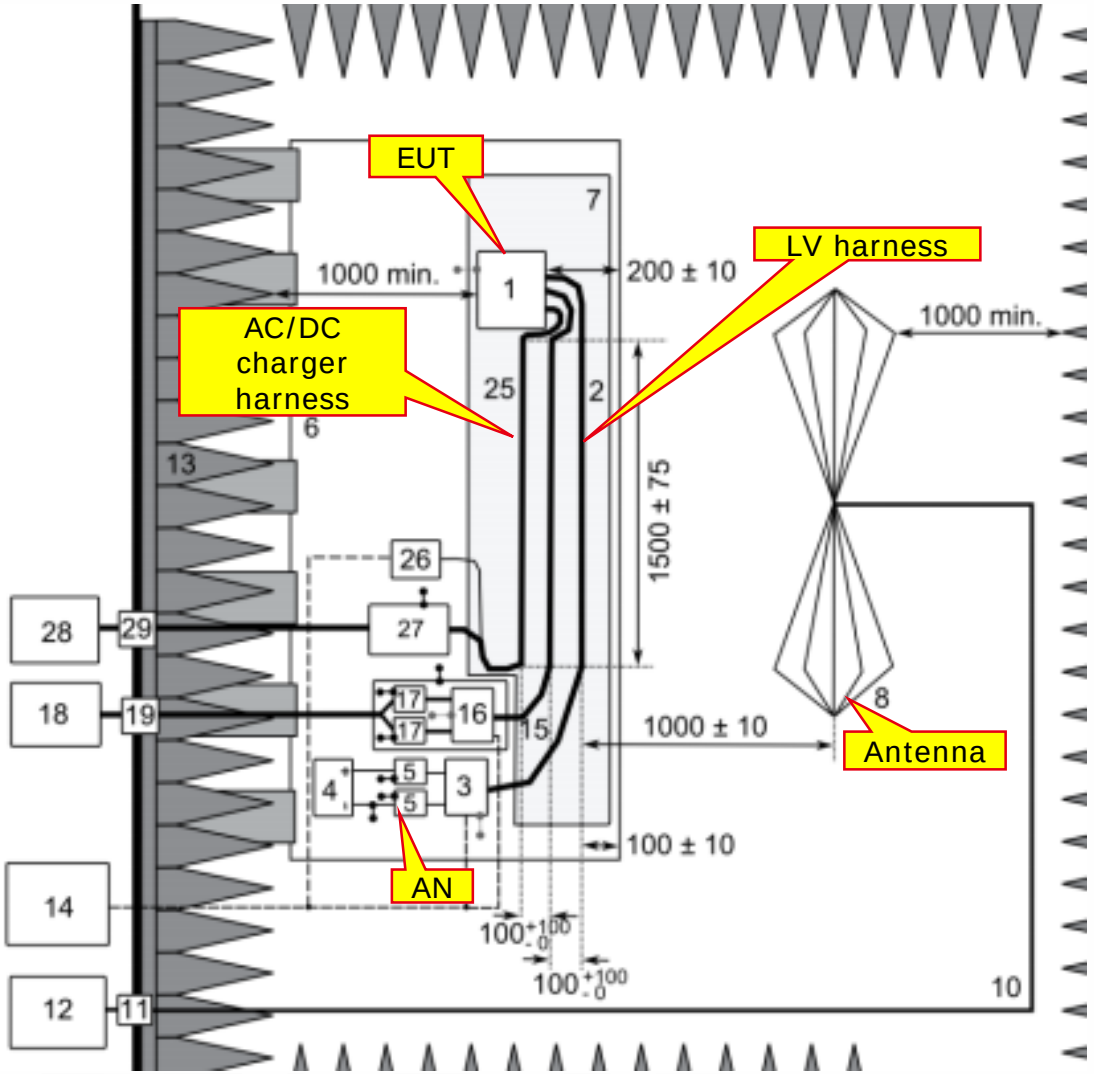
- Referring CISPR25(2002 Ed.2)
  - Distance 1m
  - RBW : 120kHz
  - For BB meas. :QP or PK
  - For NB meas. :AV
- Only Broadband test in charge mode

Conducted Emissions Test

- IEC61000-6-3 (CE for AC)
- CISPR22 (CE for Network)
- IEC61000-3-2,3-3 (harmonics , Voltage change , flicker)

Frequency [MHz]	Broadband Limit [dBuV/m] Distance 1m	Narrowband Limit [dBuV/m] Distance 1m
30 - 75	62-52	52-42
75 – 400	52-63	42-53
400 – 1000	63	53

Radiated emission for ESA

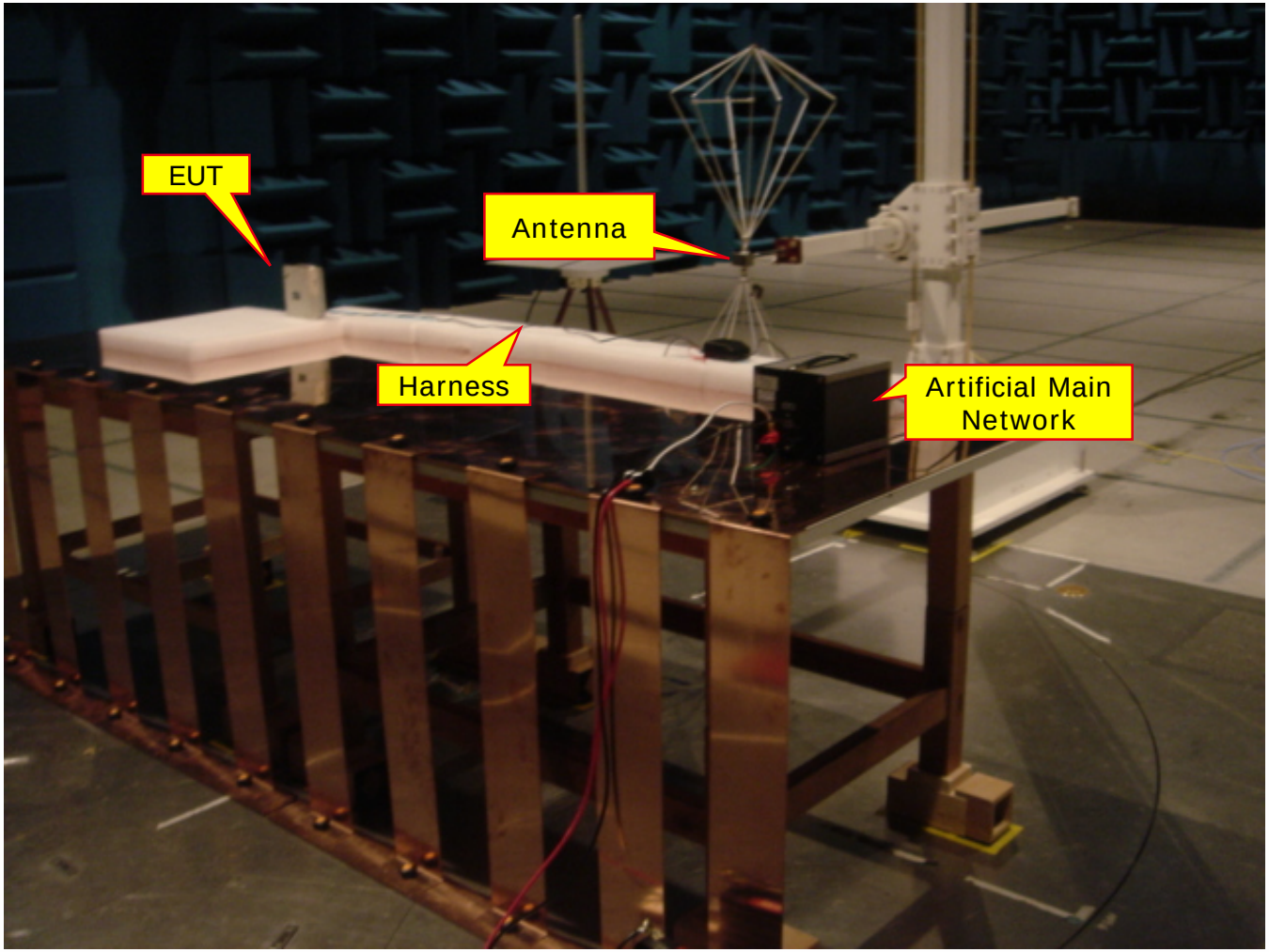


Legend:

1 ESA (grounded locally if required in test plan)
2 LV Test harness
3 LV Load simulator (placement and ground connection according to CISPR 25 paragraph 6.4.2.5)
4 Power supply (location optional)
5 LV Artificial network (AN)
6 Ground plane (bonded to shielded enclosure)
7 Low relative permittivity support ($\varepsilon_r \leq 1.4$)
8 Biconical antenna
10 High-quality coaxial cable e.g. double-shielded (50 Ω)
11 Bulkhead connector
12 Measuring instrument
13 RF absorber material
14 Stimulation and monitoring system
15 HV harness
16 HV load simulator
17 HV AN
18 HV power supply
19 HV feed-through
25 AC/DC charger harness
26 AC/DC load simulator (e.g. Programmable Logic Controller (PLC))
27 50µH Line Impedance Stabilization Network (LISN) (AC) or HVAN (DC)
28 AC/DC power supply
29 AC/DC feed-through

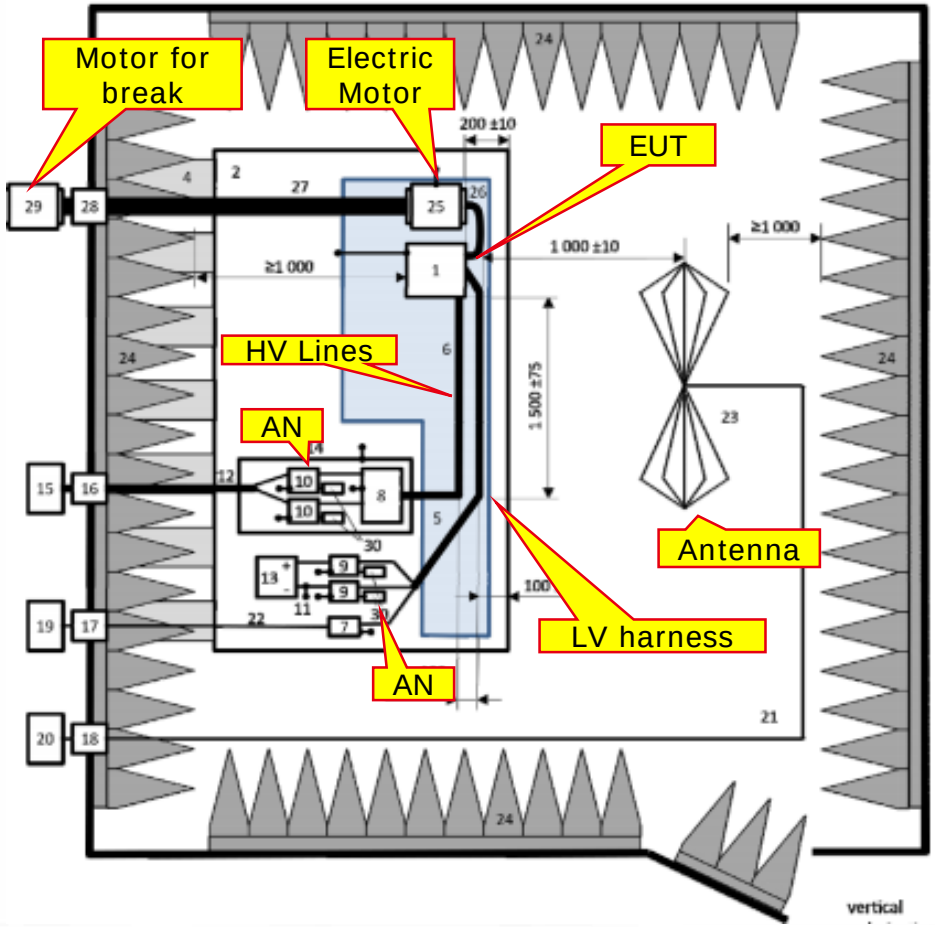
Example of Setup

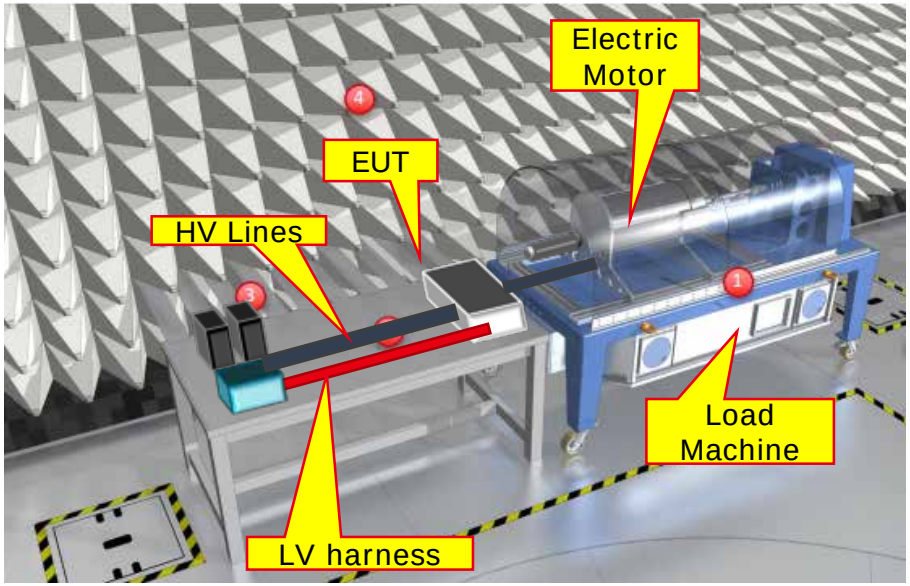
- Example of Setup for Radiated emission measurement for ESA



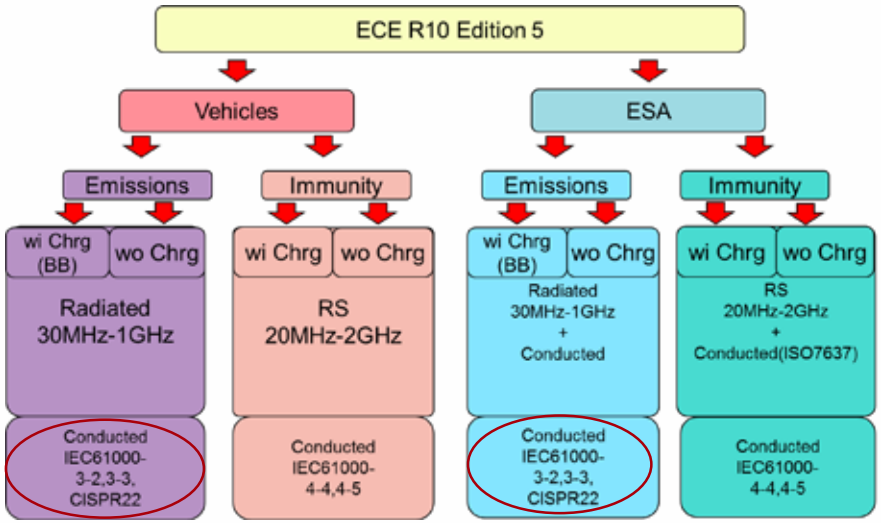
Example of Setup

- Example of Setup for Radiated emission measurement for ESA with shielded power supply systems with electric motor





Conducted Emission measurement for "REESS charging mode coupled to the power grid“



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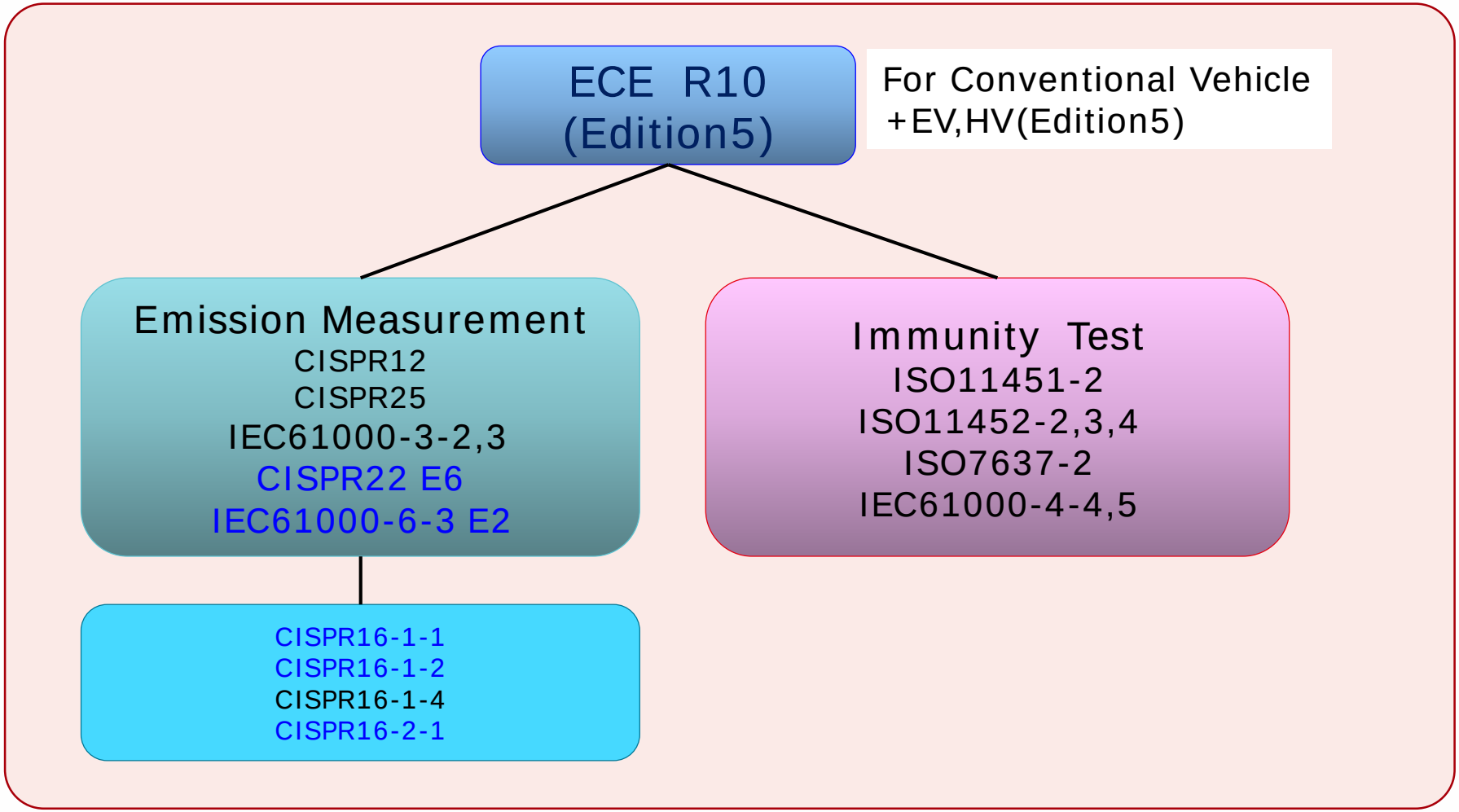
International Standards Referred to by R-10

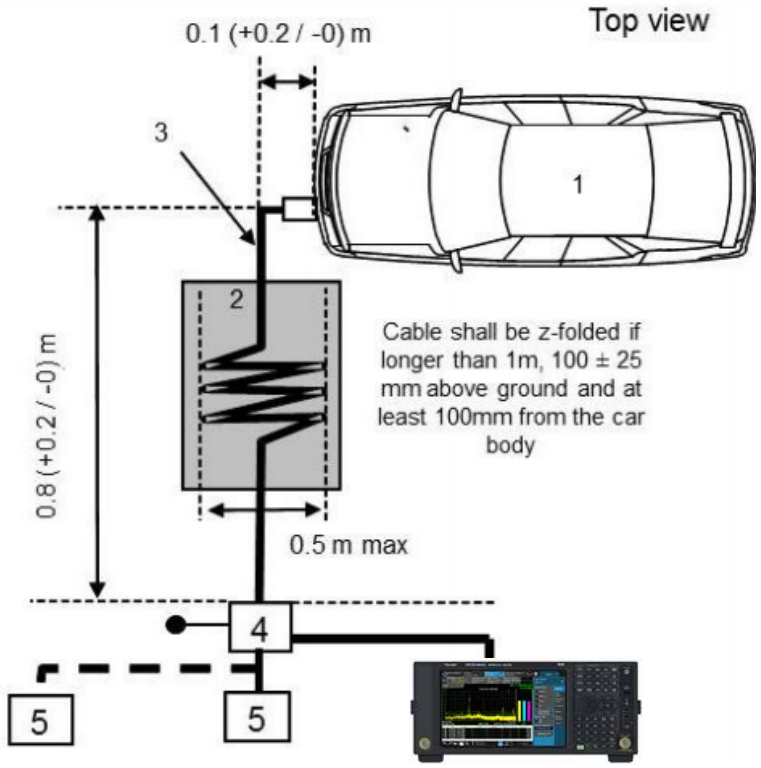
	Test	Standard	Ed.3⇒ Ed.5
Annex4	BB Radiation from Vehicle	CISPR12 E5+amd1(2005)	Adding Charging mode(Ed4)
Annex5	NB Radiation from Vehicle	CISPR12 E5+amd1(2005)	Except charging mode(Ed4)
Annex6	Immunity of Vehicle to Radiation	ISO11451-2 E3(2005)	Adding Charging mode(Ed4)
Annex7	BB Radiation from ESA	CISPR25 E2+Cor 2004	Adding Charging mode(Ed5)
Annex8	NB Radiation from ESA	CISPR25 E2+Cor 2004	Except charging mode(Ed5)
Annex9	Immunity of ESA to Radiation	ISO11452-1..5	
Annex10	Immunity of ESA to Conduct ion	ISO7637-2 E2	
Annex11	Harmonics generated on AC line	IEC61000-3-2,12	(Ed4)
Annex12	Voltage change, fluctuation , flicker	IEC61000-3-3,11	(Ed4)
Annex13	Conducted emission on AC,DC line	CISPR16-2-1,1-2	(Ed4)
Annex14	Conducted emission on Net/Telecom	CISPR22 E6	(Ed4)
Annex15	EFT/Burst on AC,DC line	IEC61000-4-4 E2	(Ed4)
Annex16	Surge on AC,DC line	IEC61000-4-5 E2	(Ed4)
Annex17	Harmonics generated on AC line for ESA	IEC61000-3-2,12	(Ed5)
Annex18	Voltage change, fructuation , flicker for ESA	IEC61000-3-3,11	(Ed5)
Annex19	Conducted emission on AC,DC line for ESA	CISPR16-2-1,1-2	(Ed5)
Annex20	Conducted emission on Net/Telecom for ESA	CISPR22 E6	(Ed5)
Annex21	EFT/Burst on AC,DC line for ESA	IEC61000-4-4 E2	(Ed5)
Annex22	Surge on AC,DC line for ESA	IEC61000-4-5 E2	(Ed5)

International Standards Referred to by Conducted emission measurement in REESS charge mode



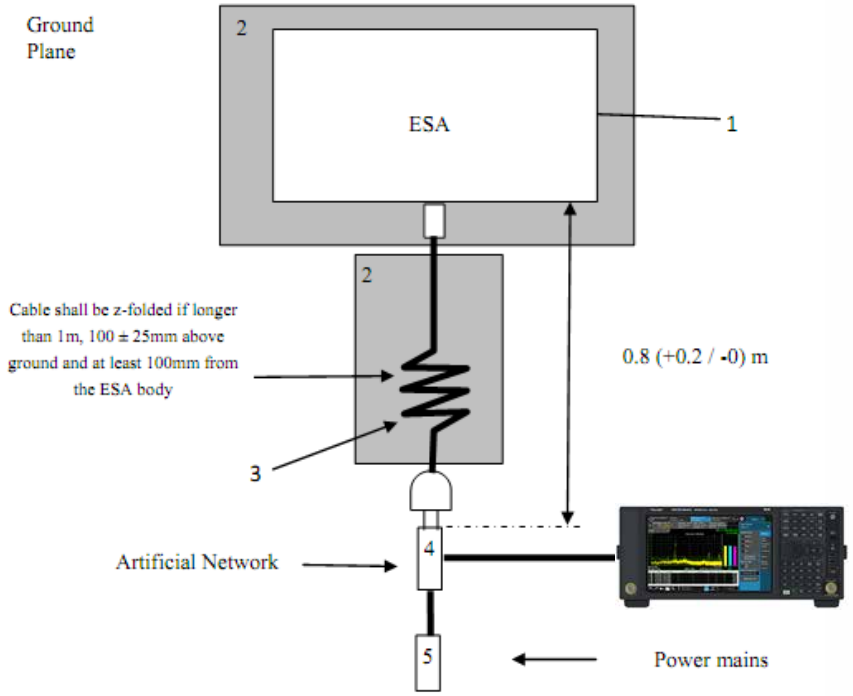
Conducted Emission Measurement on AC/DC power source

Test setup for Conducted Emission Measurement on AC/DC power source



Legend:

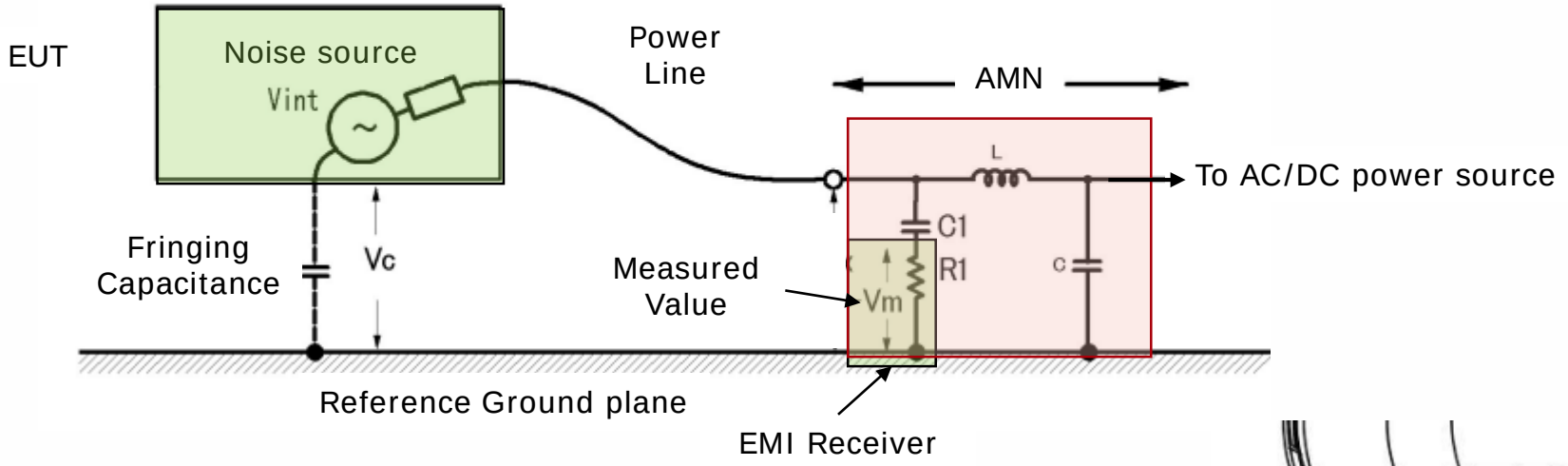
1	Vehicle under test
2	Insulating support
3	Charging cable
4	Artificial network(s) grounded (for AC or DC power lines)
5	Power mains socket
6	Measuring receiver



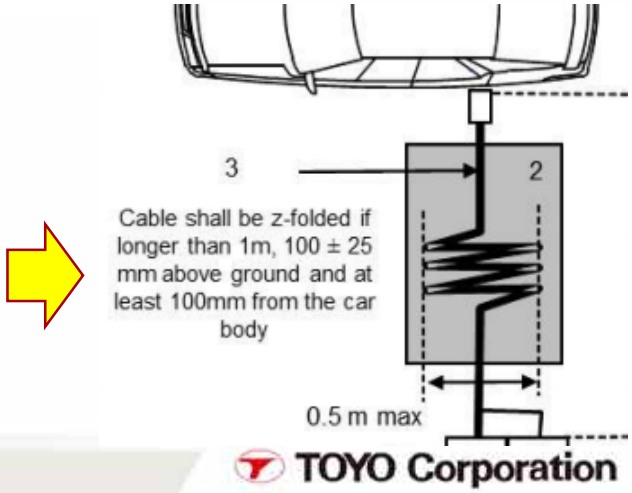
Legend:

1	ESA under test
2	Insulating support
3	Charging cable
4	AC or DC Artificial network(s) grounded
5	Power mains socket
6	Measuring receiver

Concept of Conducted Emission Measurement on AC/DC power source

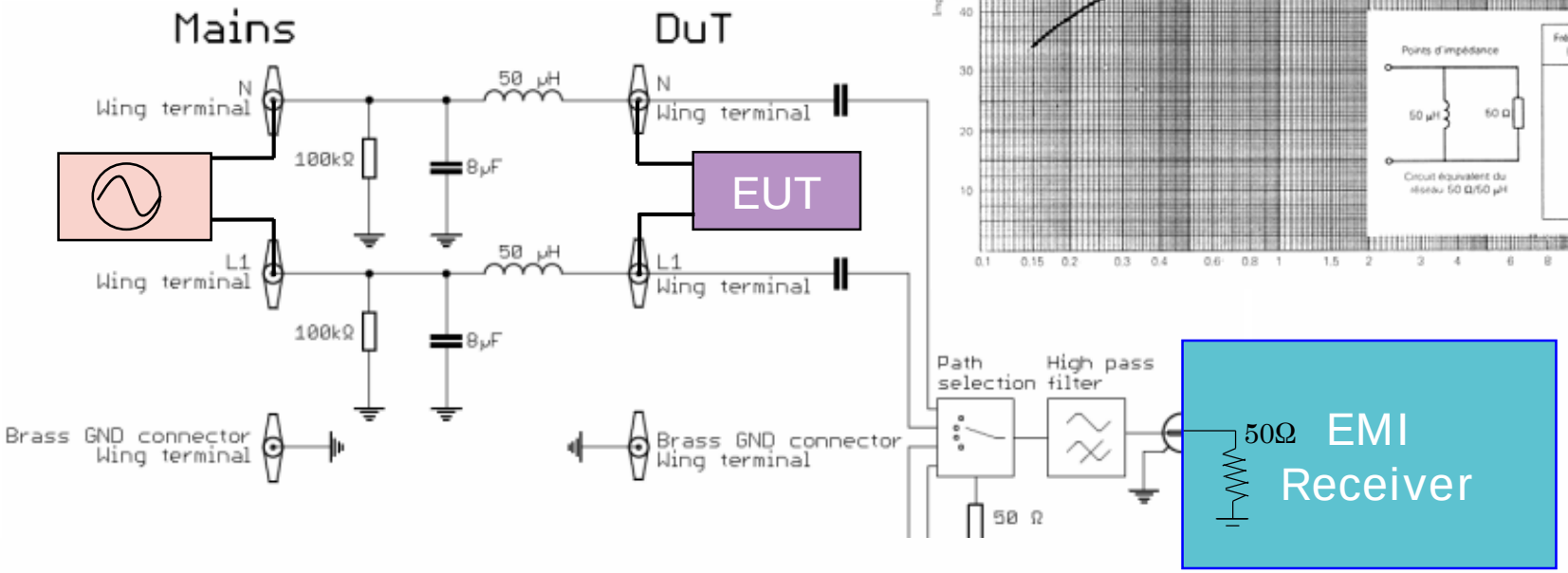


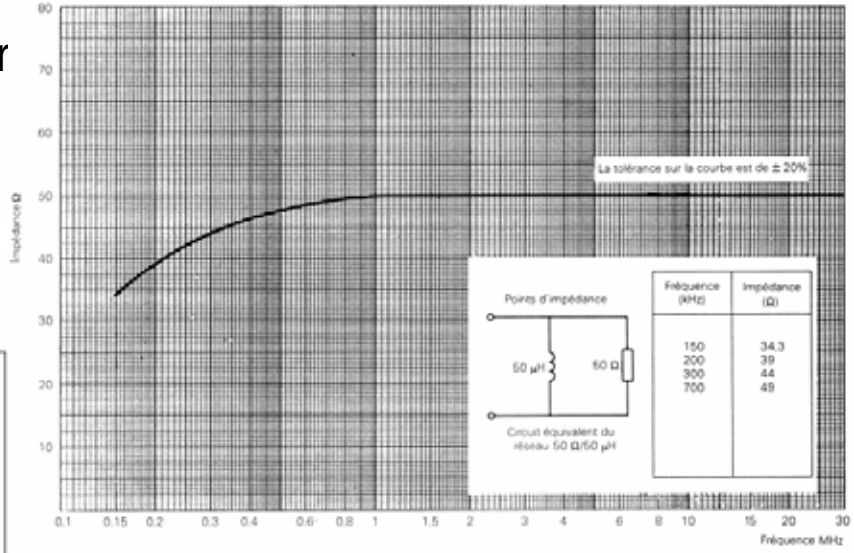
- Vm≒Vint – Vc
  - Vc must be fixed to get stable measurement value (Vm)



Artificial Main Network(AMN) for AC power Source

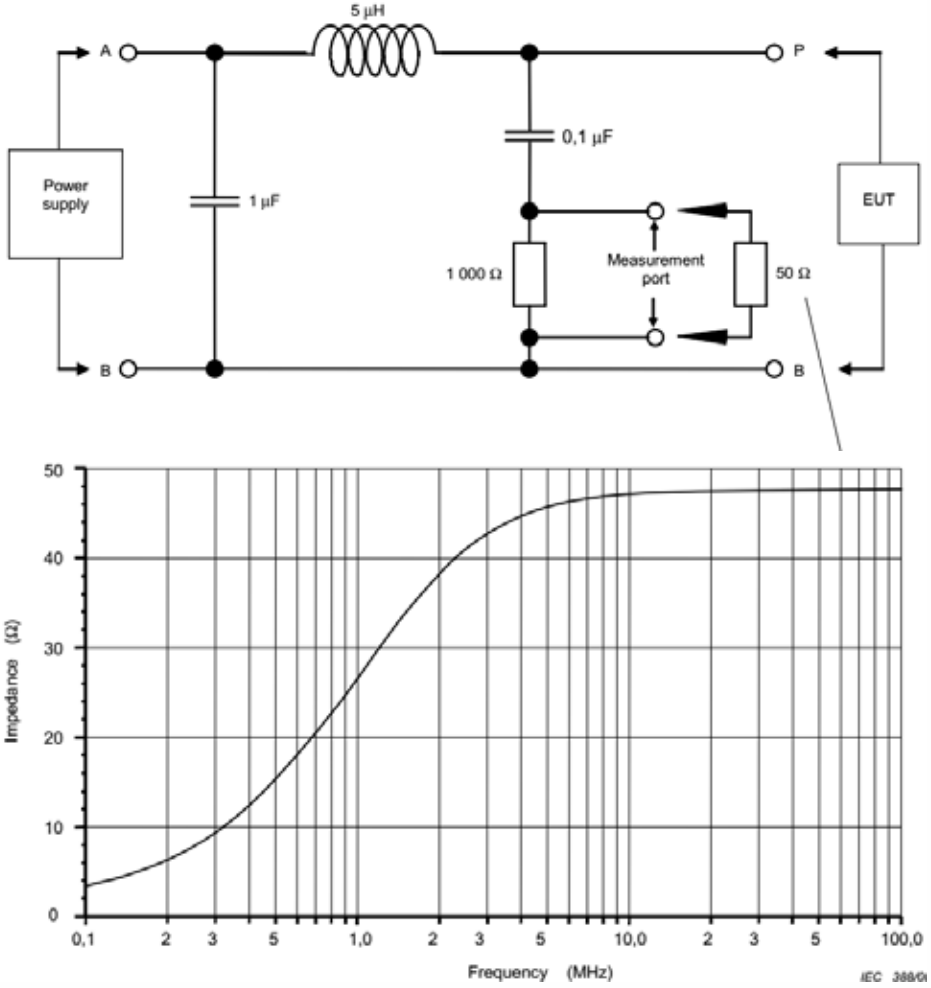
- Use 50μH/50Ω (CISPR16-1-2 4.3) V-network
  - Set the impedance of the EUT terminal to the specified value
  - Suppress noise entering from power supply





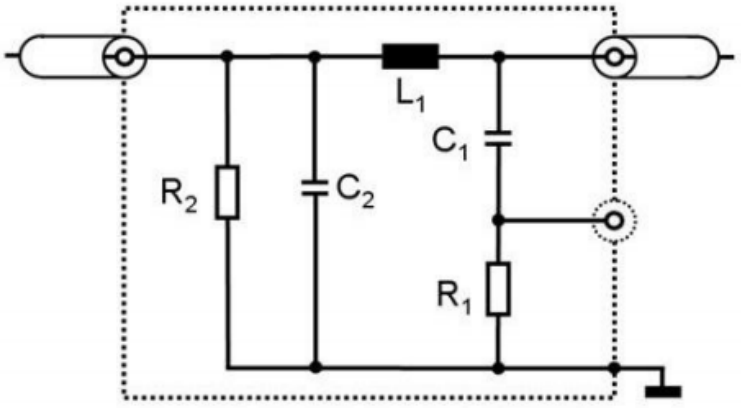
Artificial Main Network(AMN) for DC power Source

- Use 5μH/50Ω (CISPR25 Annex E) AMN for DC power source.



Artificial Main Network(AMN) for High Voltage DC power source

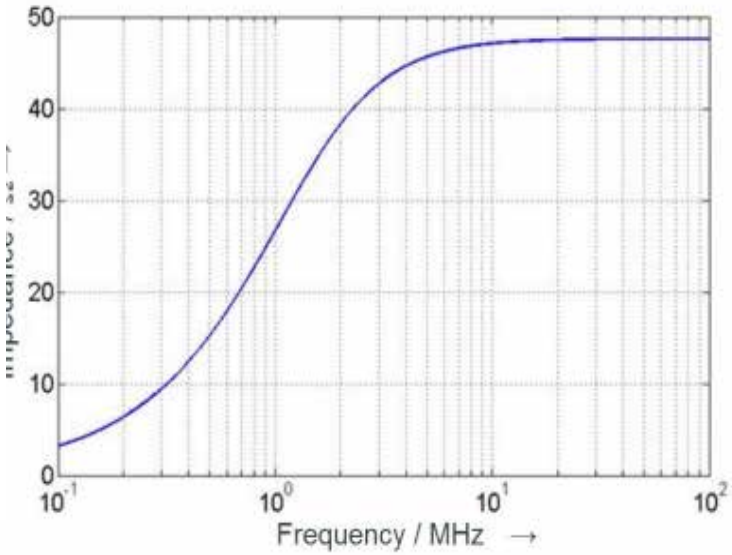
- Use 5μH/50Ω (R10 Appendix 8)



Legend	*C_2: 0.1 μF*
L_1: 5 μH	R_1: 1 kΩ
C_1: 0.1 μF	R_2: 1 MΩ (discharging C_2 to < 50 V_{dc} within 60 s)

re 2

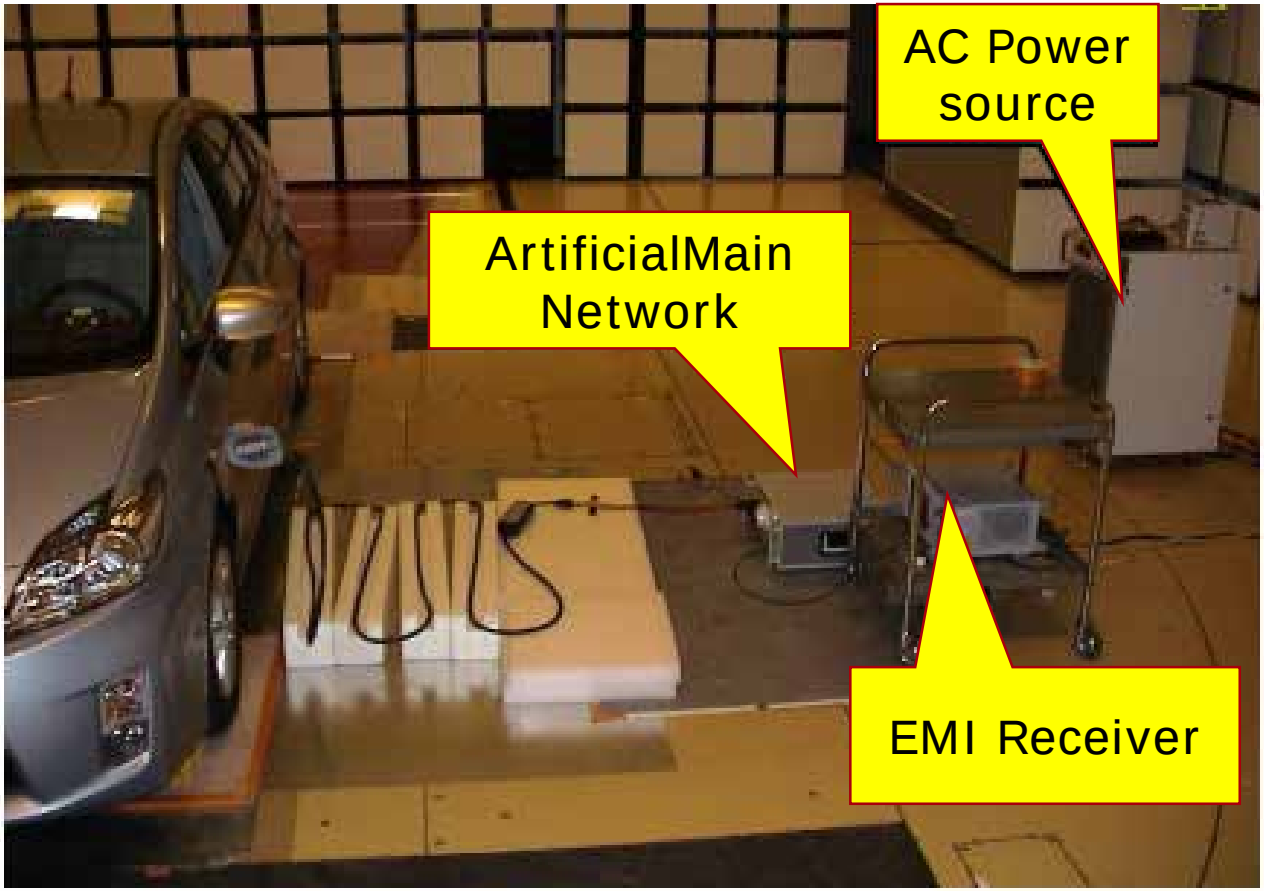
edance of HV artificial network



∗Adding a resistor for Discharging High Energy

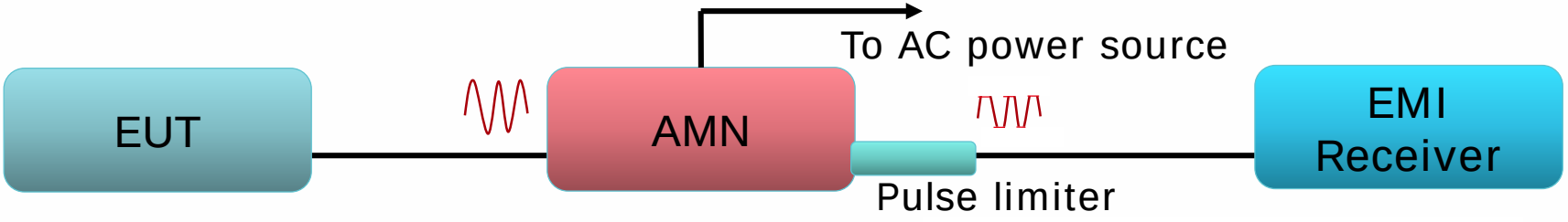
Example of Setup

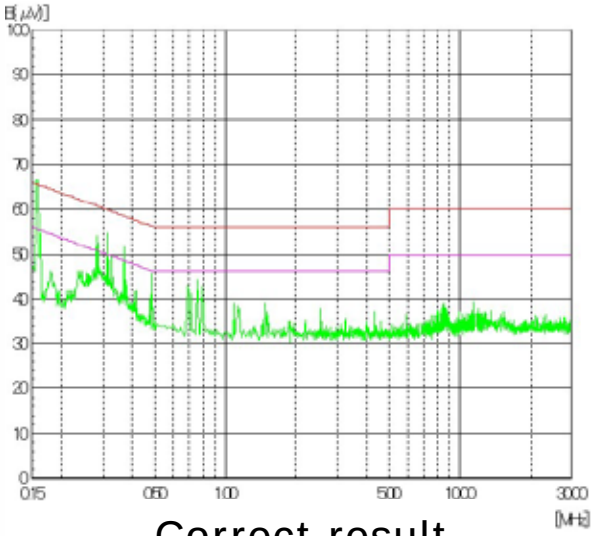
- Example of Setup for Conducted emission measurement for Vehicle



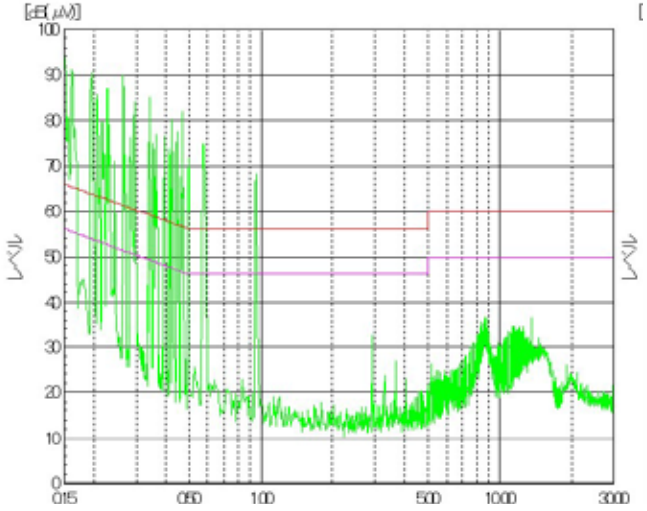
Notes on Conducted emission measurement

- The mixer in the EMI receiver or the pulse limiter which has used to protect the EMI receiver may be into saturation by inputting the high voltage broadband noise.
- Use Attenuator instead of pulse limiter for correct measurement.





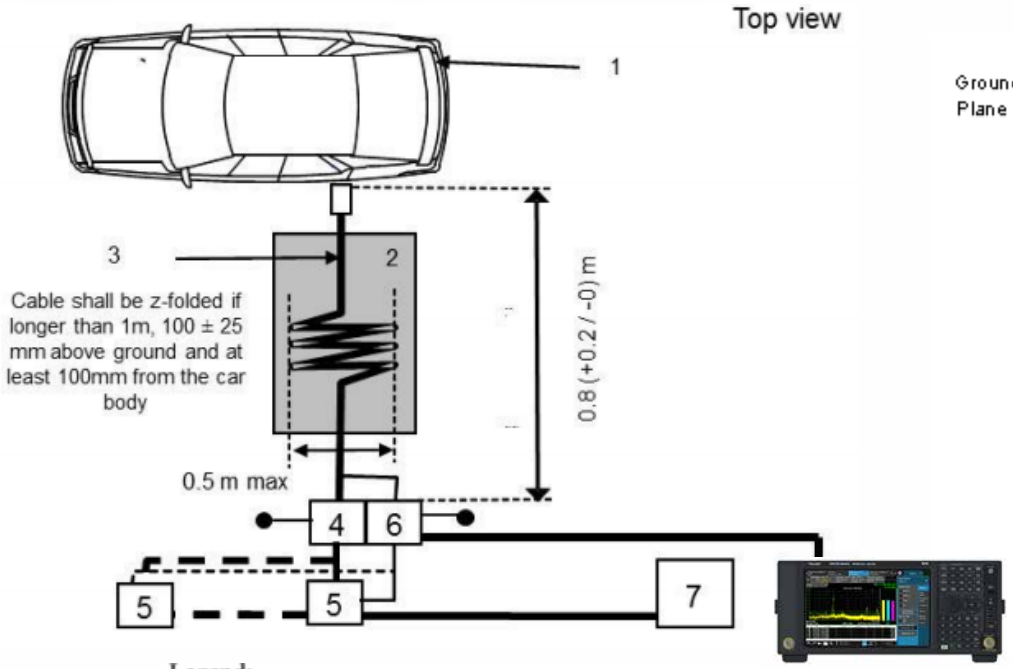
Correct result



Wrong results by saturation

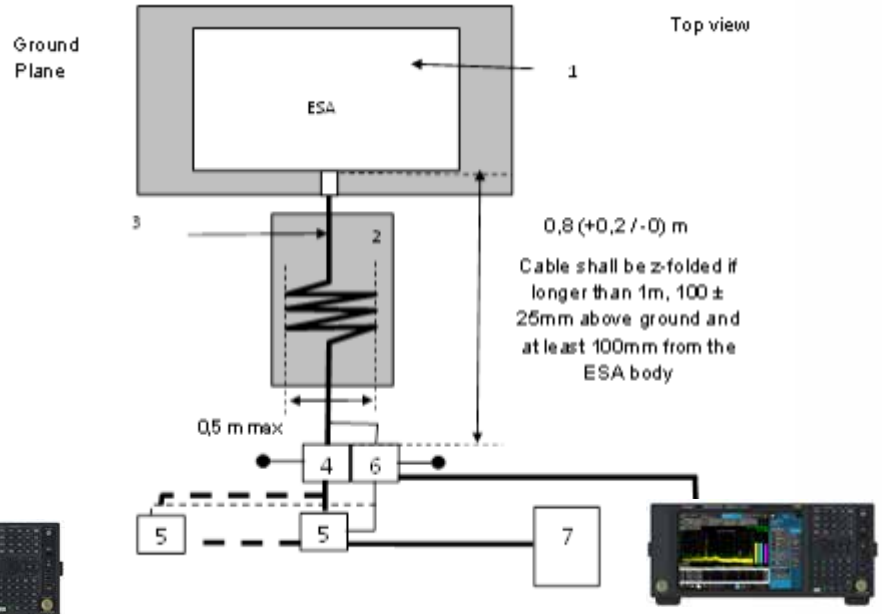
Conducted emission measurement on the network and telecommunication

Test setup for conducted emission measurement on the network and telecommunication



Legend:

1	Vehicle under test
2	Insulating support
3	Charging / communication cable
4	AC or DC artificial network(s) grounded (for AC or DC power lines)
5	Power mains socket
6	Impedance stabilization(s) grounded (for communication lines)
7	Charging station
8	Measuring receiver

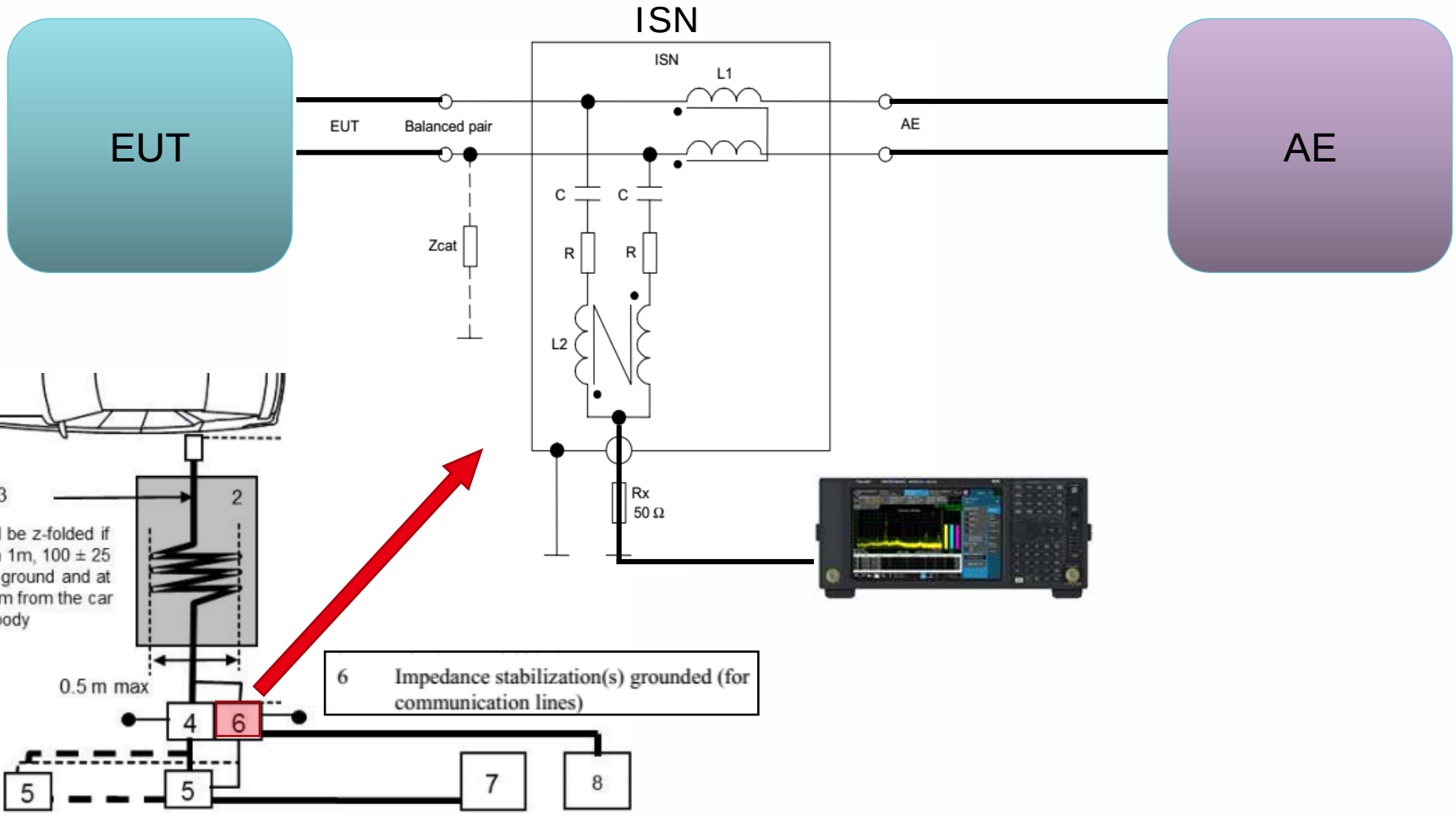


Legend:

1	ESA under test
2	Insulating support
3	Charging / communication cable
4	AC or DC Artificial network(s) grounded
5	Power mains socket
6	Impedance stabilization(s) grounded
7	Charging station
8.	Measuring receiver

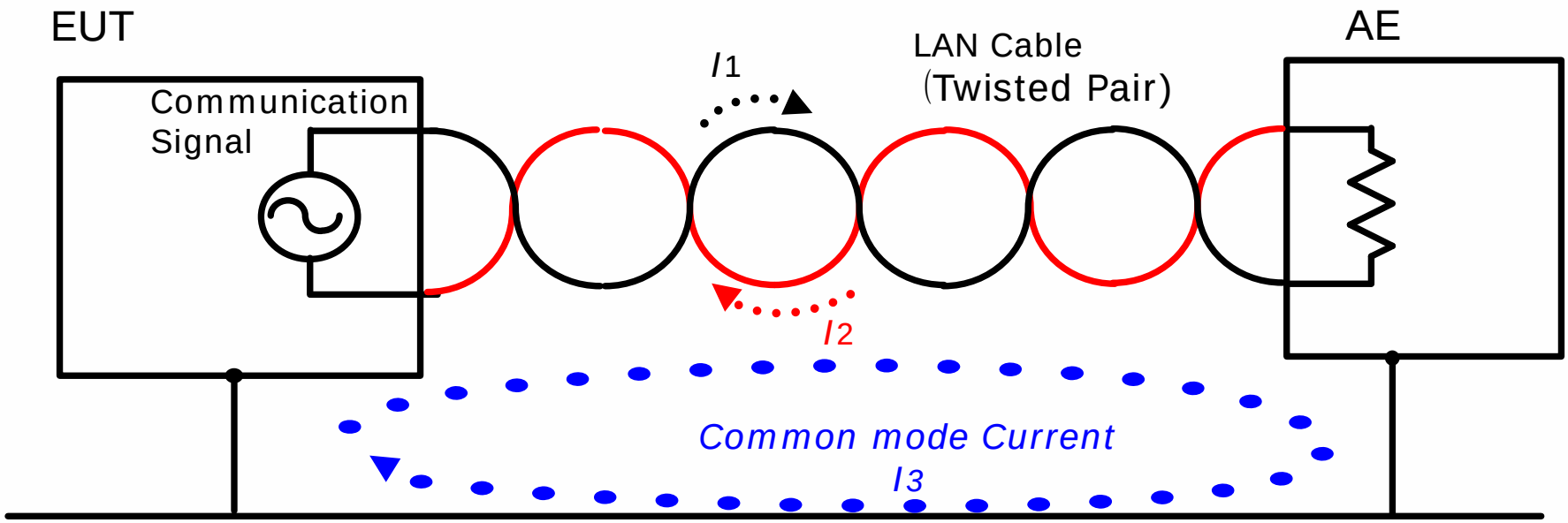
Theory of conducted emission measurement on the network and telecommunication ports.

- Use ISN(Impedance Stabilization network) to measure the common mode noise of communication line



Cause of the disturbance to generate from the network and telecommunication ports

- The common mode noise from various circuits in EUT outputs from a network and telecommunication port
- Communication signal itself becomes the common mode noise and outputs it from a telecommunication port



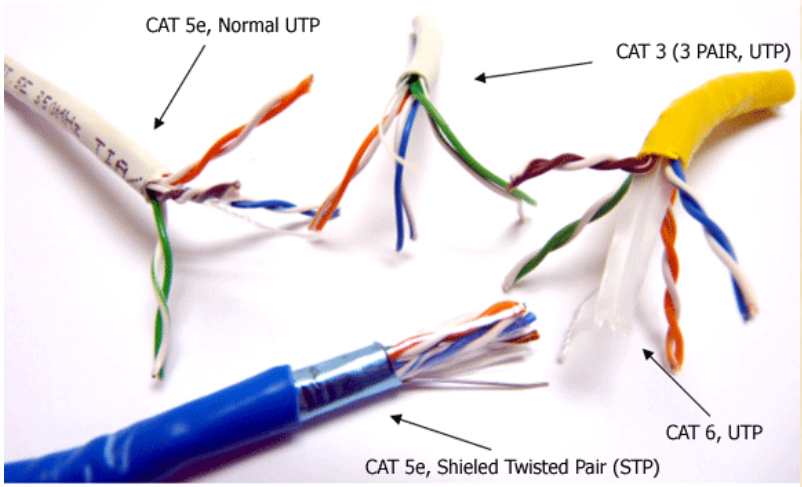
*A common mode current *I3* generates by the unbalance in the communication route

To measure the common mode noise of the network and telecommunication port exactly

- The LCL value of the ISN and the cable influences the measurement result

  *LCL(Longitudinal conversion loss): The ratio that the signal of the differential mode converts into the signal of the common mode

- It is necessary to use the cable of the category specified by the manufacturer

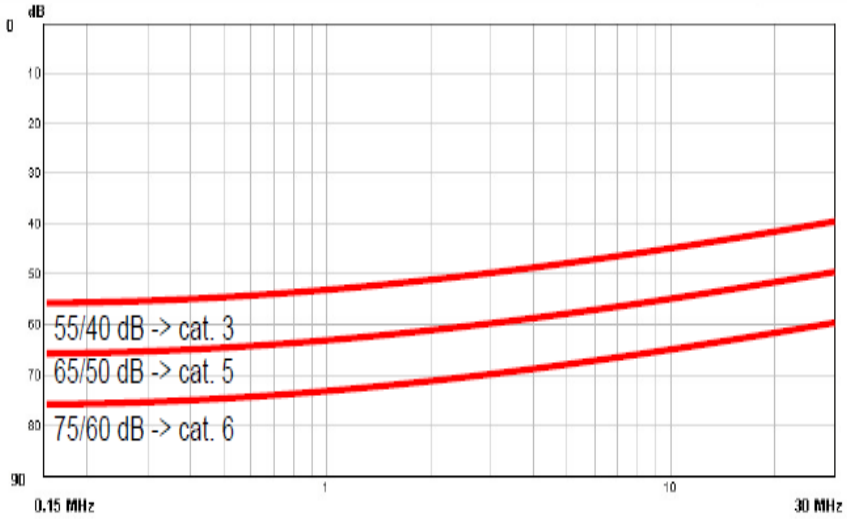


TIA Twisted-pair cable categories

Category	Makeup	Data rate	Network compatibility
Cat-1	2 pair	1 Mbps	Analog voice
Cat-3	4 twisted pairs	10 Mbps – 2 pair	10BaseT
Cat-5	4 twisted pairs	10 Mbps – 2 pair 100 Mbps – 2 pair	10BaseT 100BaseTX
Cat-5e	**4 twisted pairs**	**10 Mbps – 2 pair 100 Mbps – 2 pair 1 Gbps – 4 pair**	**10BaseT 100BaseTX 1000BaseTX**
Cat-6	**4 twisted pairs**	**1 Gbps – 4 pair 10 Gbps – 4 pair** (55m)	**1,000BaseTX 10,000BaseTX**
Cat-6a	**4 twisted pairs**	**10 Gbps – 4 pair**	**10,000BaseTX**

To measure the common mode noise of the network and telecommunication port exactly

- It is necessary to use the ISN having the LCL value corresponding to the category specified by the manufacturer
- LCL value for Category 3, 5, 6 and Example of how to realize ISN's LCL

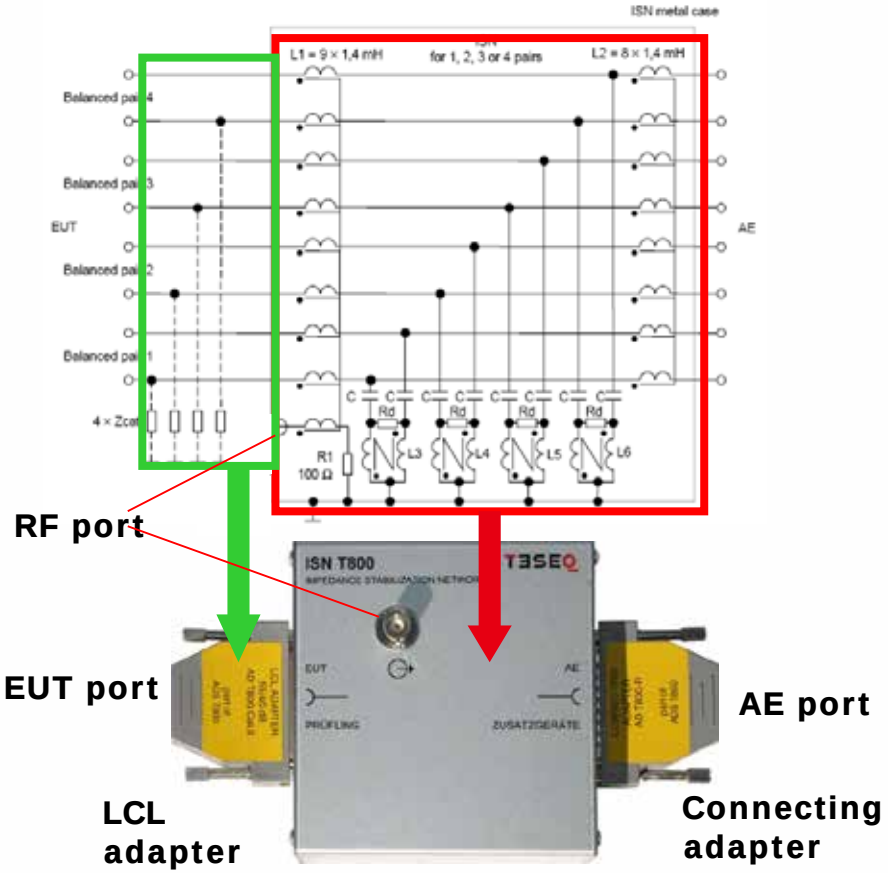


Above Category 3 $LCL = 55 - 10\log[1 + (\frac{f}{5})]$ dB

Above Category 5 $LCL = 65 - 10\log[1 + (\frac{f}{5})]$ dB

Above Category 6 $LCL = 75 - 10\log[1 + (\frac{f}{5})]$ dB

f:MHz



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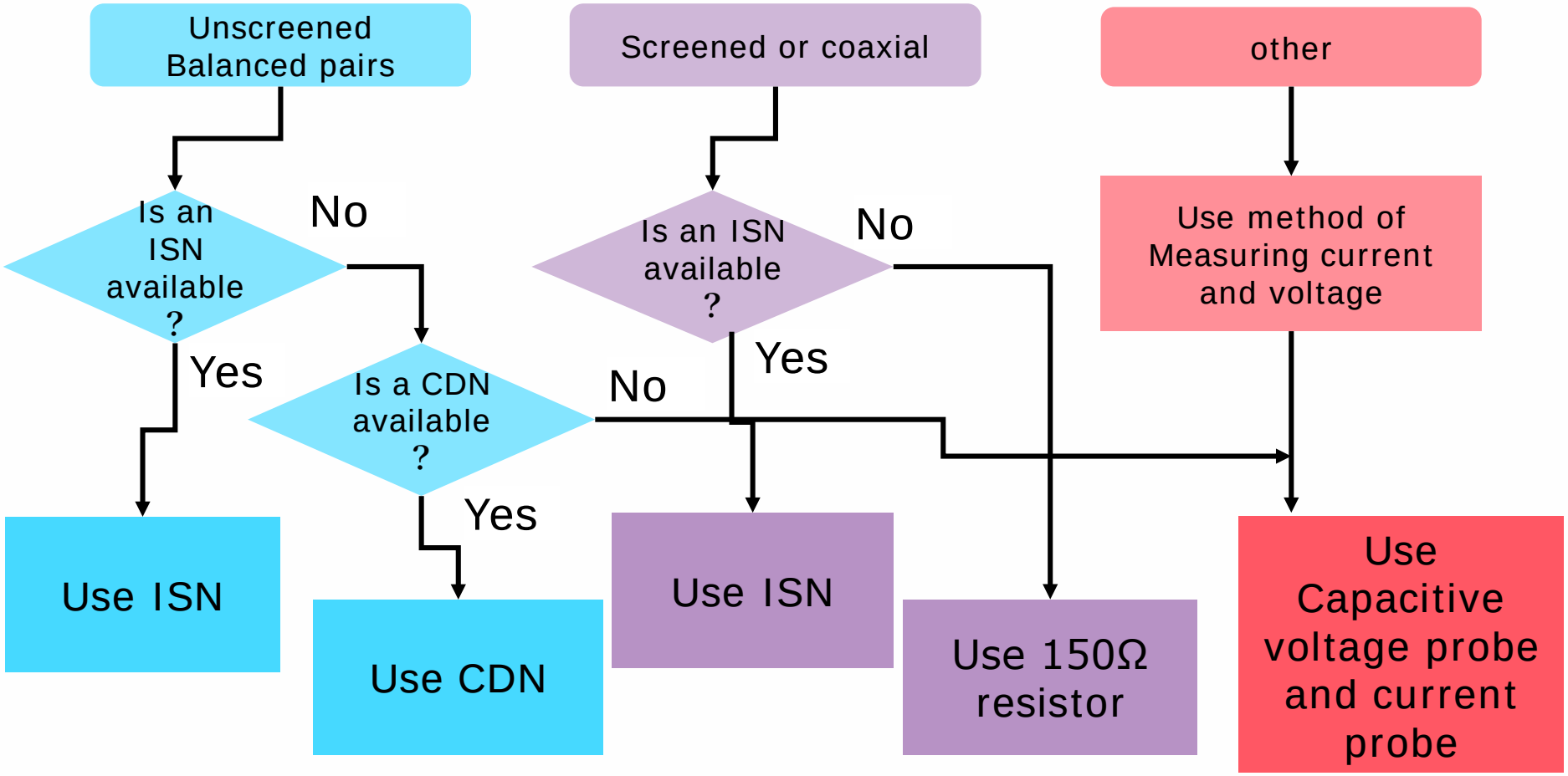
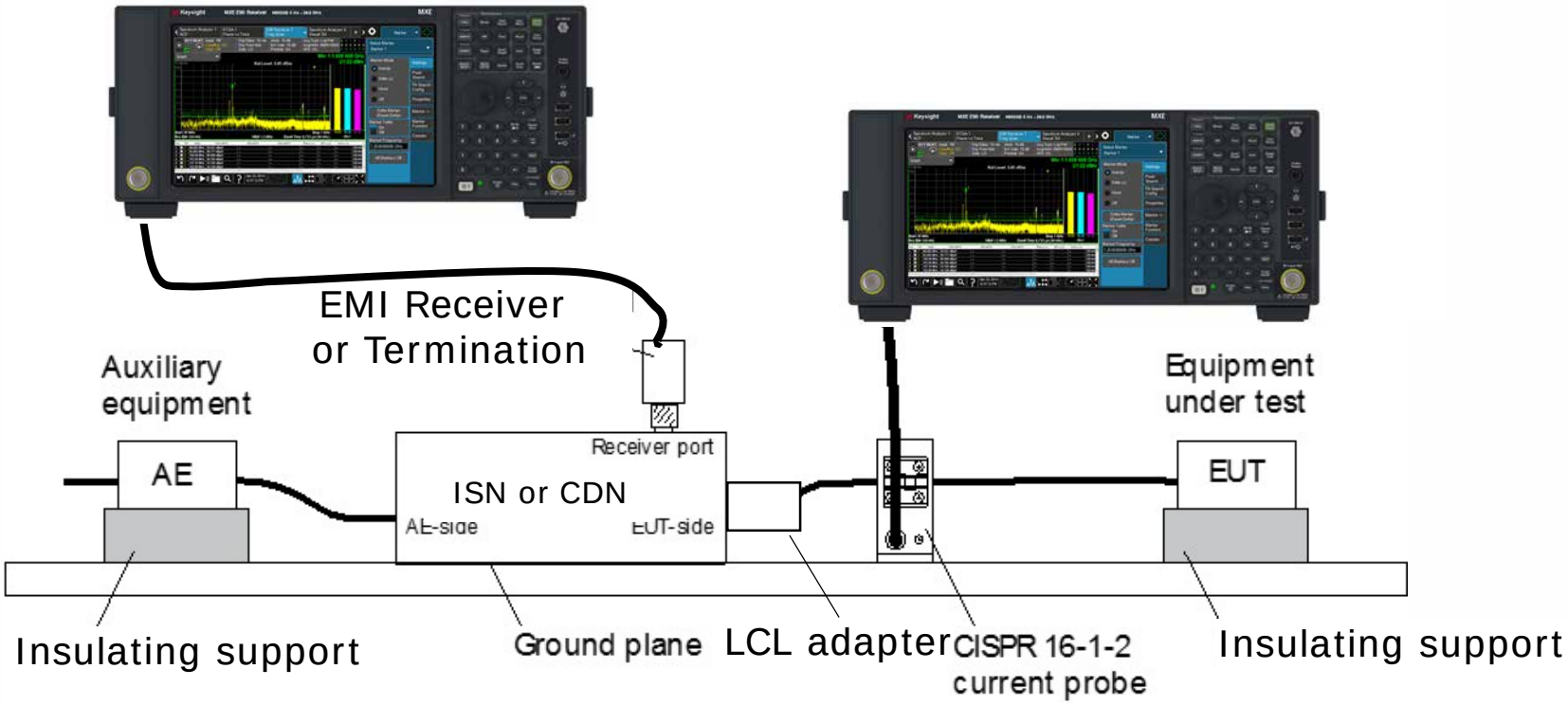
Test method selection rules (CISPR22 Annex C)

- Determining the test method depending on the type of cable and port



Measurement setup using ISN / CDN

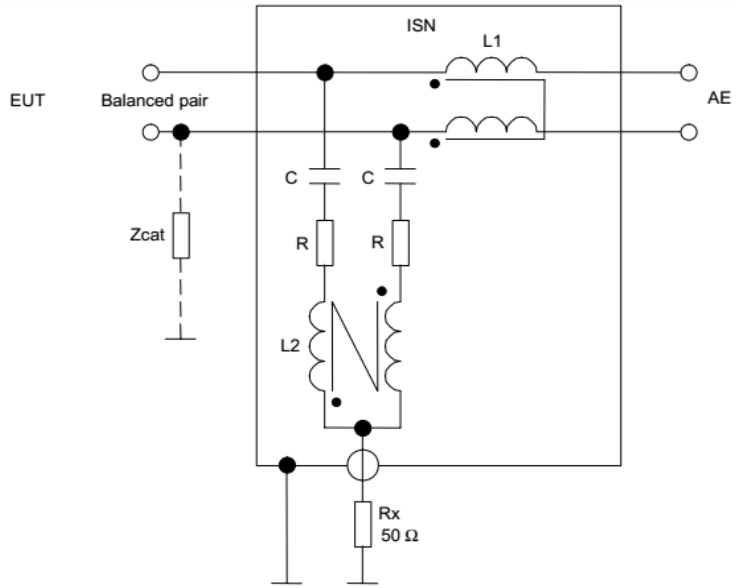
- For unscreened/screened twisted pair or coaxial port



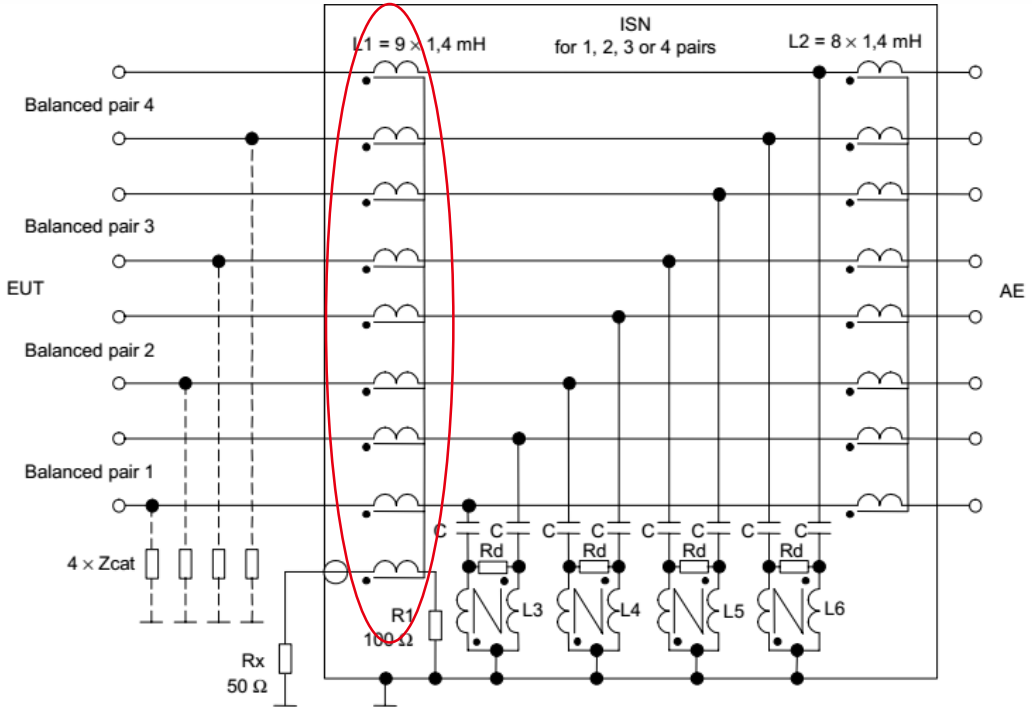
*It is not necessary to apply both voltage and current

ISN

ISN for unscreened/screened twisted pair



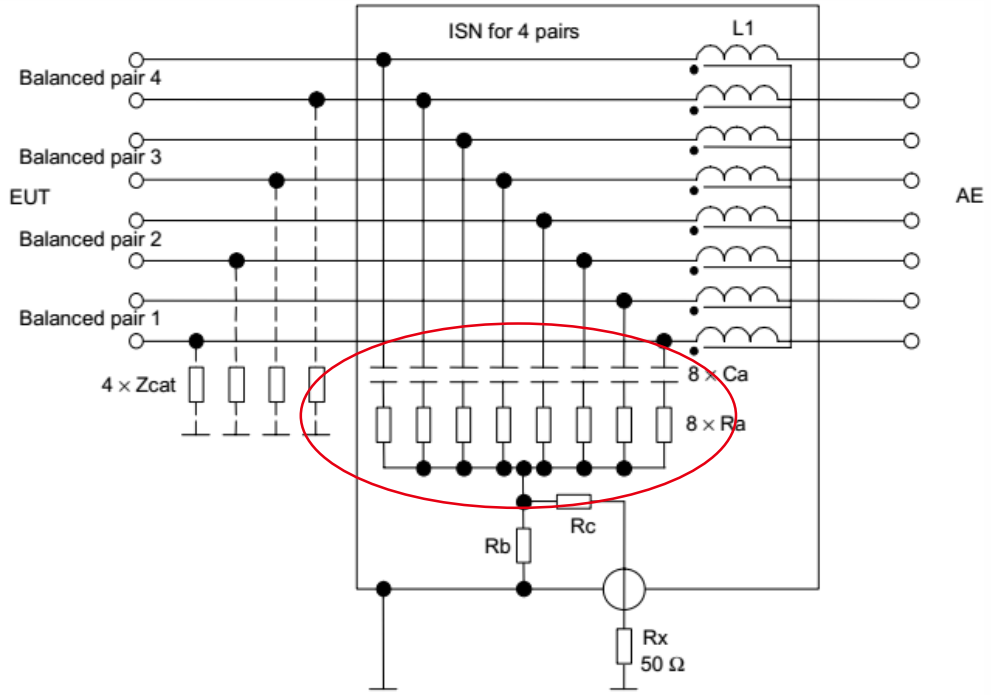
ISN for 1 pair



ISN for 1 – 4 pairs

ISN

ISN for unscreened/screened twisted pair



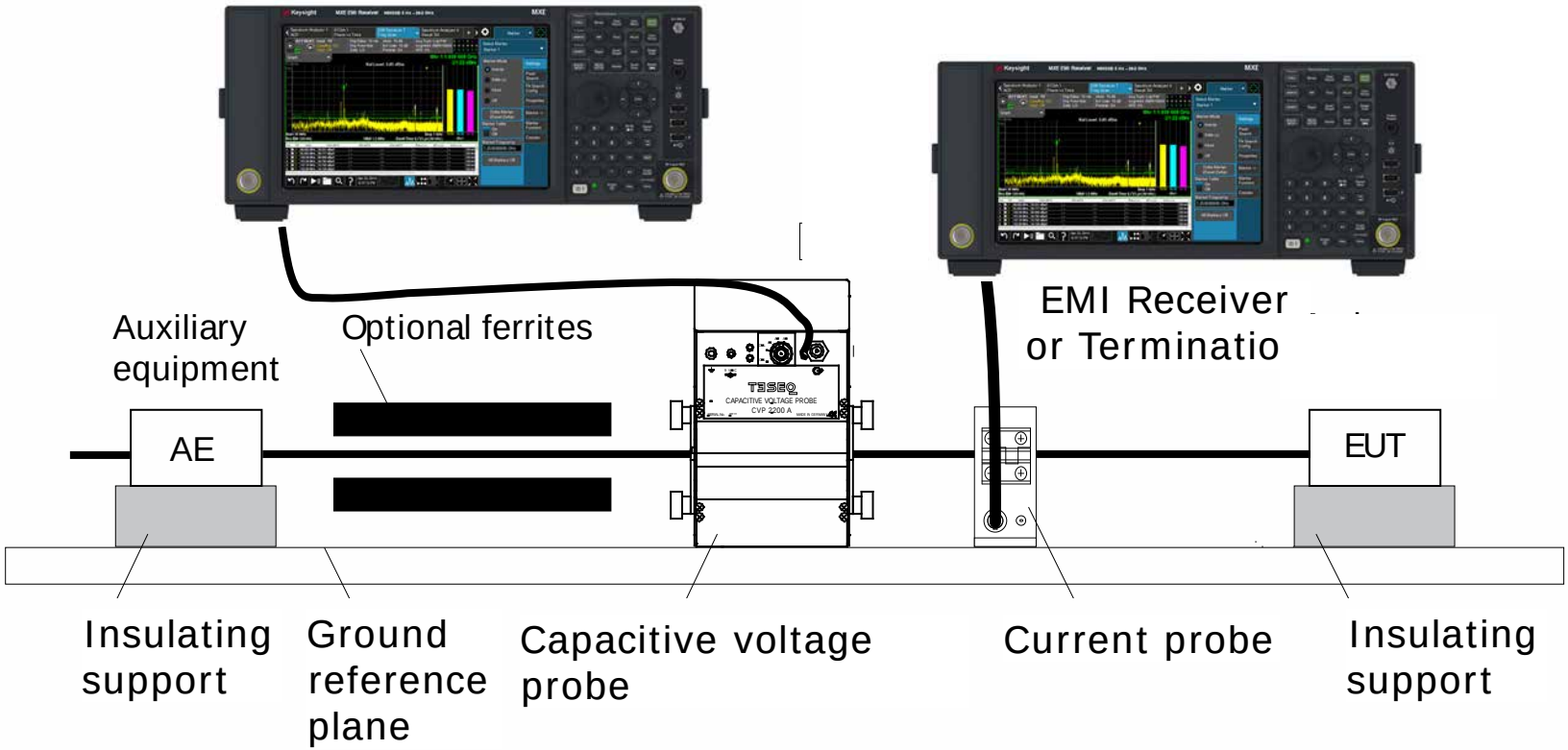
ISN for unscreened 4 pairs(for 8 lines)

The ISN of this circuit shall be used for the measurement of the port where all the terminals are used

ISNs for one pair (2 lines) ISN for a pair of balanced lines and ISNs for two pairs (for 4 lines) for two pairs of balanced lines are required.

Measurement using Capacitive voltage probe and current probe

- For other cables



*Apply both voltage and current

Exceptions in conjunction with Conducted emission measurement in REESS charge mode

- When there is no direct connection to a telecommunication which includes network telecommunication service additional to the charging communication service, Annex 14 and Annex 20 shall not apply.
- When network and telecommunication access of the vehicle/ESA uses power line Transmission (PLT) on its AC/DC power lines, Annex 14/Annex20 shall not apply.

Annex14… Conducted emission measurement on Net/Telecom for Vehicle

Annex20… Conducted emission measurement on Net/Telecom for ESA

*For more information, see “7.20 Exceptions”

Overview

Part 1

Movement of international standard ECE R10 for Vehicle and ESA EMC Standards for Vehicles & ESA

Part 2

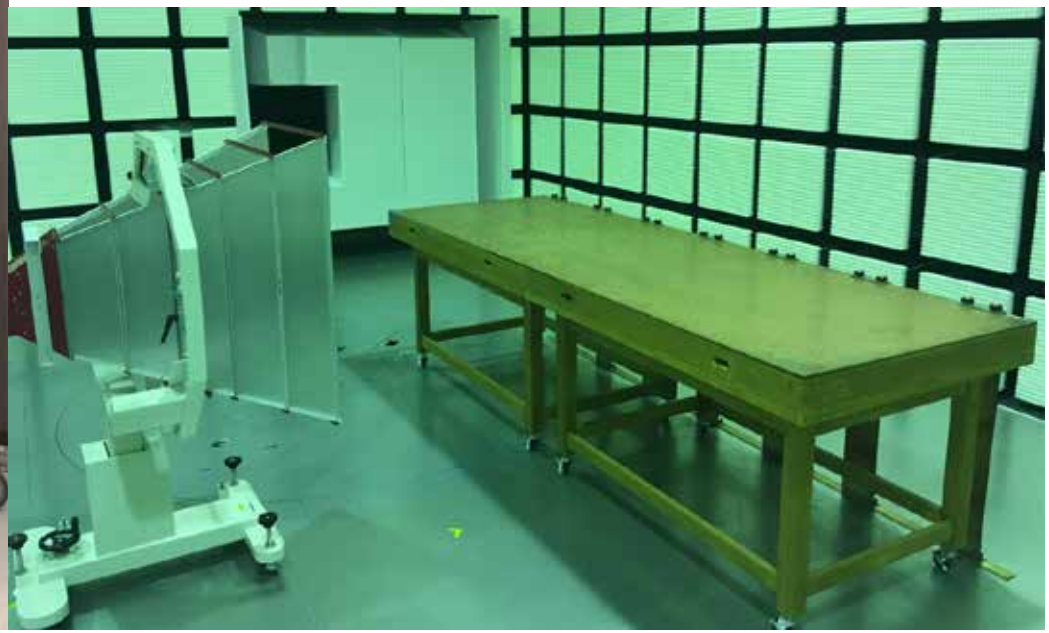
EMC Test System

Part2 Introduction

- EMC Test System
  - System overview
  - Monitoring EUT
  - Problem about immunity testing
- Image processing system
  - LED ON/OFF
  - Needle meter
  - 7 segment display
  - Image change detection
- New dynamometer

EMC Test System

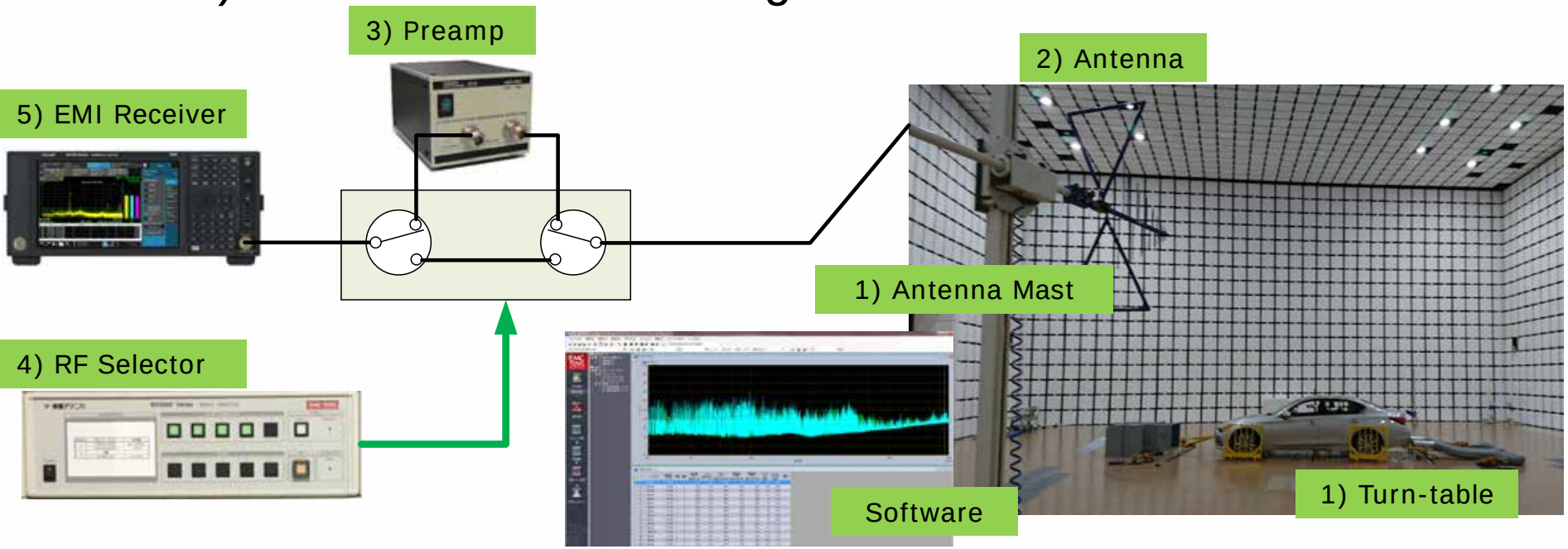
EMS(Immunity) Test System



EMC Test System

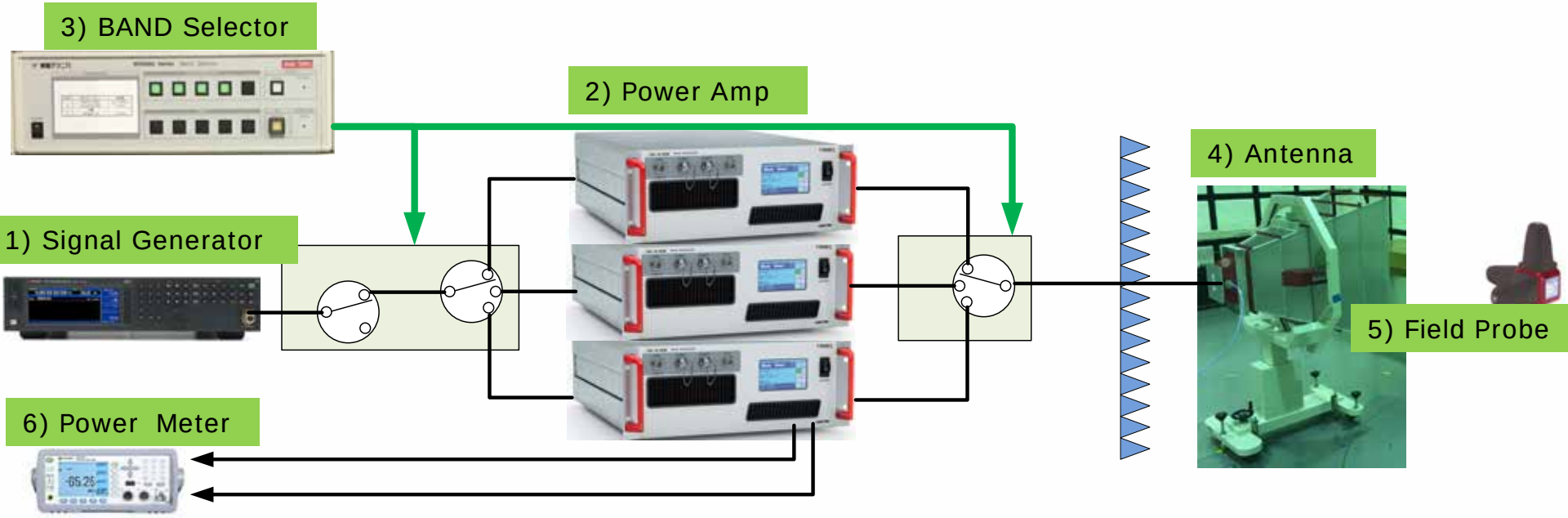
EMI Test System

1) Control the antenna mast and turn-table
2) Receive the noise via the antenna (or AMN)
3) Amplify the receiving noise by the preamplifier
4) Switching the RF path
5) Measure the receiving level with EMI Receiver



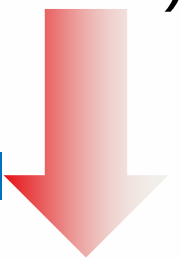
EMC Test System

- EMS(Immunity) Test system
  1) Generate the interference signal
  2) Amplify it by the power amplifier
  3) Change the frequency bands (with interlock function)
  4) Generate an interference field with transmitting antenna
  5) Measure the electromagnetic field with a field probe
  6) Measure the output power with a power meter and sensor



EUT Monitoring

- Voltage, Current, Frequency
- CAN(Controller Area Network)
- S/N, SINAD
- Record the reading data from measurement instruments
- Check the status (pass/fail)



Record the result as a “fail”

Change the test level and check the status again (pass/fail)

Human Check

Overlay the parameters

- Overlay the frequency, level, polarization, modulation by text generator
- Watch the EUT status and interference signal parameters on the one monitor
- Record the video data during immunity testing and recheck it after testing.

Problem about human check

- Heavy work for operator
- Watch EUT status for long time
- Repeatability issue
  - Ø Unclear judgement criteria
  - Ø Individual differences
  - Ø Oversight due to long test time
  - Ø Difficult to check a few displayed screen simultaneously

⇒Automatically test with image processing technology

Image processing

- Analyze the image data
  - 》Recognize the shape
  - 》Recognize what the object is

→OCR, face authentication, iris authentication

Recently it has been installed in vehicles.

Obstacles recognize three-dimensionally and that is used to prevent accidents.

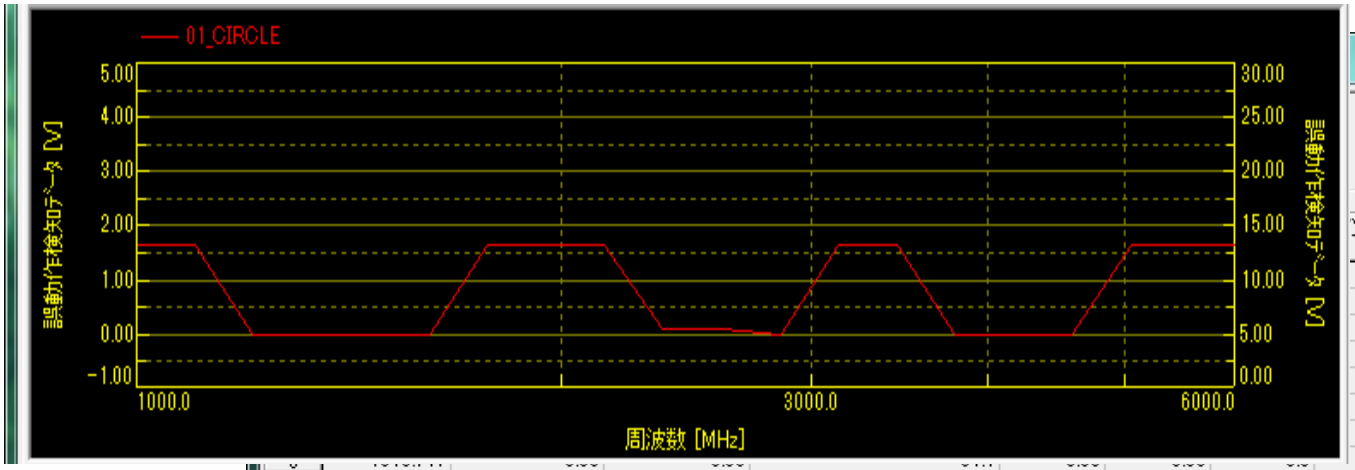
Intruder detection

※FUJITSU KYUSHU SYSTEMS

※TOSHIBA

Quantification of images

- Image processing system
  Automatically detect EUT status by software
  →Saving the test time and cost
  Quantitative evaluation of EUT status



Reading

詳細情報..
表示設..
閉じる

ンテナ高さ [cm]	アンテナ偏波	測定時刻	01_CIRCLE [V]
155.0	水平	10:08:18	1.65
155.0	水平	10:08:22	1.65
155.0	水平	10:08:25	0.00
155.0	水平	10:08:29	0.00
155.0	水平	10:08:33	0.00
155.0	水平	10:08:37	0.00
155.0	水平	10:08:40	1.64
155.0	水平	10:08:44	1.65
155.0	水平	10:08:48	1.67
155.0	水平	10:08:51	0.09
155.0	水平	10:08:55	0.09
155.0	水平	10:08:59	0.00
155.0	水平	10:09:03	1.66
155.0	水平	10:09:06	1.65
155.0	水平	10:09:10	0.00
155.0	水平	10:09:14	0.00
155.0	水平	10:09:18	0.00
155.0	水平	10:09:22	1.65

9	2143.589	3.00	0.00	90.7	0.00	0.00	0.0
10	2357.948	3.00	0.00	91.7	0.00	0.00	0.0
11	2593.742	3.00	0.00	91.6	0.00	0.00	0.0
12	2853.116	3.00	0.00	92.6	0.00	0.00	0.0
13	3138.428	3.00	0.00	90.5	0.00	0.00	0.0
14	3452.271	3.00	0.00	89.1	0.00	0.00	0.0
15	3797.498	3.00	0.00	87.8	0.00	0.00	0.0
16	4177.248	3.00	0.00	88.0	0.00	0.00	0.0
17	4594.973	3.00	0.00	89.5	0.00	0.00	0.0
18	5054.47	3.00	0.00	90.1	0.00	0.00	0.0

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Needle Meter

- Reading the needle meter

  Convert a reading of the needle meter to a numerical value

  - Setting parameters
    - Name
    - Recognized area
    - needle color
    - tolerance
  - Maximum setting: 6
  - Output type: numerical value

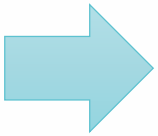
Needle Meter

Software Capture

LED

- Recognize LED ON/OFF status
  - Setting parameters
    - Name
    - Recognized area
    - ON/OFF color
    - Value(ON or OFF)
  - Maximum setting:14
  - Output type

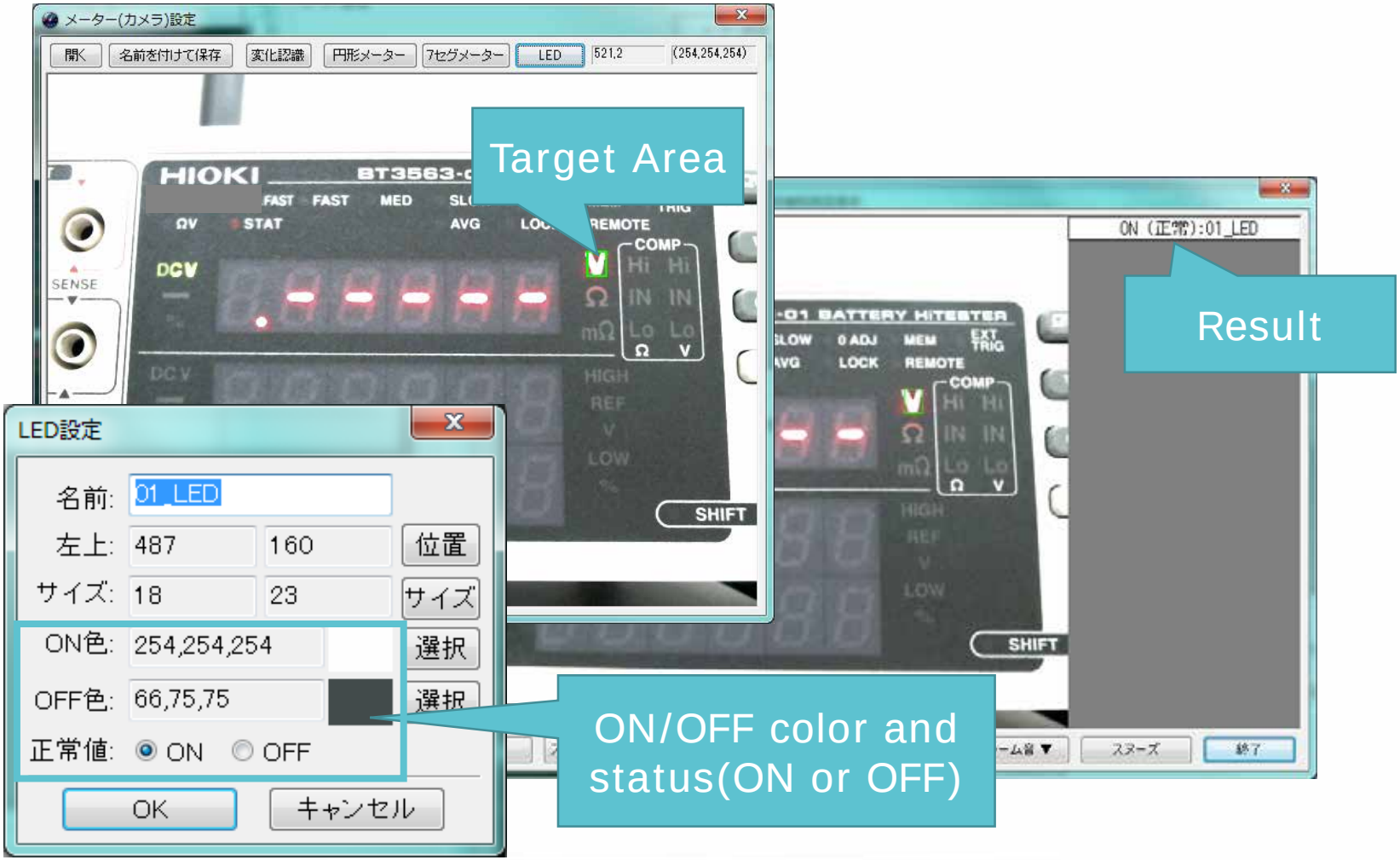
    ON = 1, OFF = 0



Save the ON/OFF status.

Automatically recognize either ON or OFF status.

LED



LED

- Recognize flashing and color of LED
  - Flashing
    - Basically setting is the same as ON/OFF setting
    - Duration time (ON and OFF)
    - Check the duration time
  - Color
    - Set multiple colors
    - Check by the color

7-segment display

Segment display

Convert the indicated 7 segment display to a numerical value

- Setting parameters
  - Name
  - Area to be recognized (including decimal point)
  - Segment size
  - Segment style
  - Tolerance
- Maximum setting：6
- Output type: numerical value

1)Save the lit situation of all segments.

2)That area will be recognized automatically.

Odometer (7-segment display)

Odometer (7-segment display)

Image Change detection

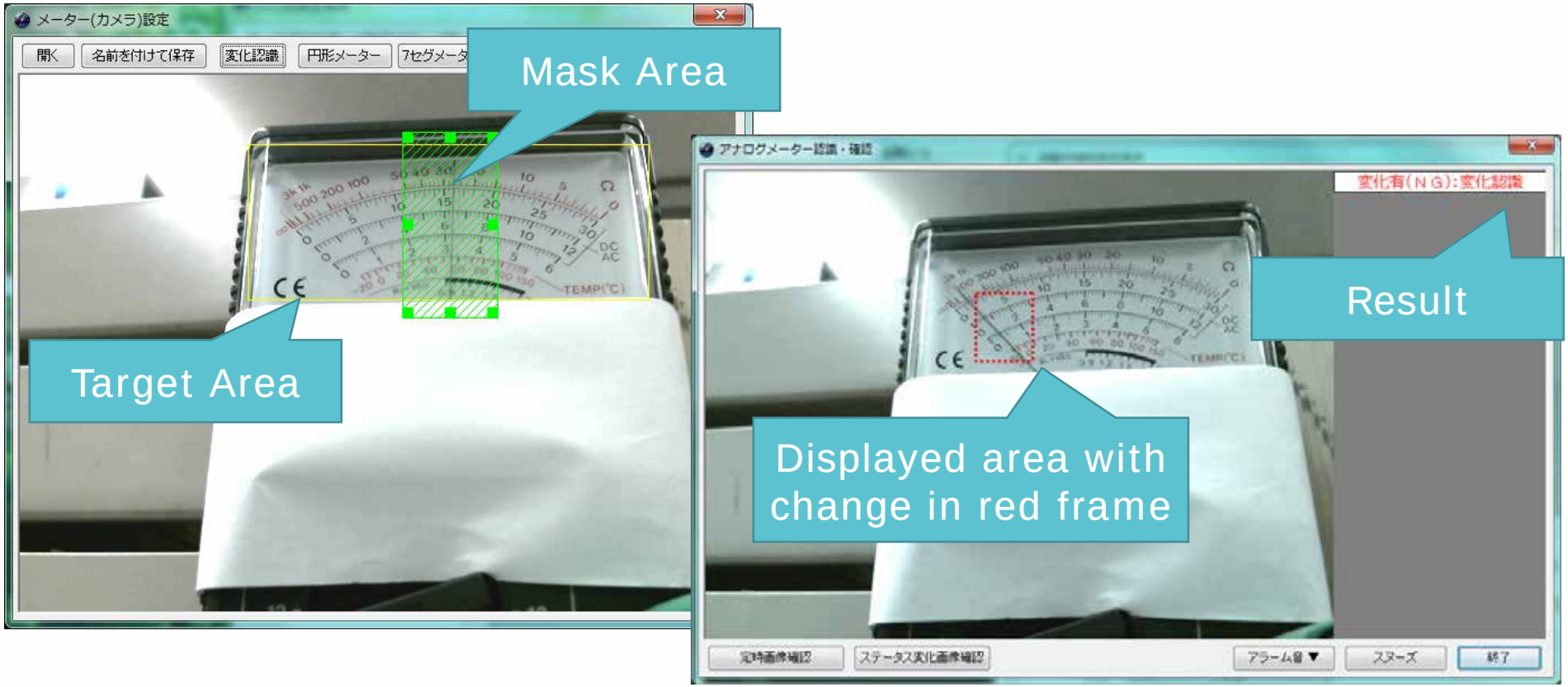
- Detect change in target area

  - Setting parameter
    - Target Area
      only 1 area
    - Mask Area
      maximum 99 areas
  - Output Type

    changed = 1, unchanged = 0

Image change detection

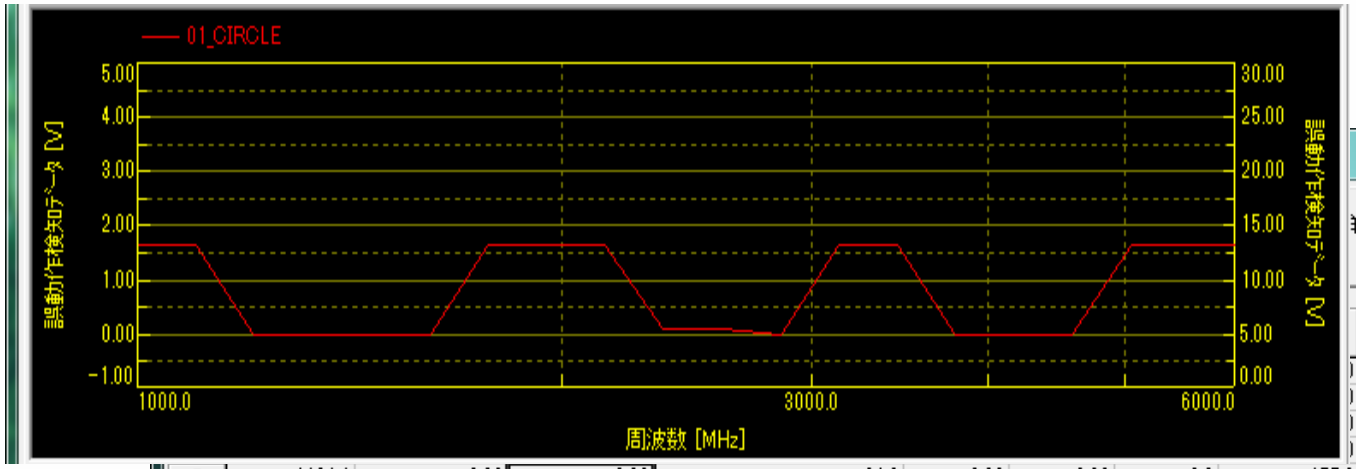
Software Capture



Recognize changes in unmasked parts in the target area

Recorded data -1-

- Save the reading data
  - Save the reading data and fail status for each frequency



詳細情報.. | 表示設定.. | クリップボードにコピー | 閉じる

									アンテナ偏波	測定時刻	01_CIRCLE [V]
5	1464.1	3.00	0.00	91.6	0.00	0.00	0.0	155.0	水平	10:08:18	1.65
6	1610.51	3.00	0.00	93.8	0.00	0.00	0.0	155.0	水平	10:08:22	1.65
7	1771.561	3.00	0.00	92.8	0.00	0.00	0.0	155.0	水平	10:08:25	0.00
8	1948.717	3.00	0.00	94.1	0.00	0.00	0.0	155.0	水平	10:08:29	0.00
9	2143.589	3.00	0.00	90.7	0.00	0.00	0.0	155.0	水平	10:08:33	0.00
10	2357.948	3.00	0.00	91.7	0.00	0.00	0.0	155.0	水平	10:08:37	0.00
11	2593.742	3.00	0.00	91.6	0.00	0.00	0.0	155.0	水平	10:08:40	1.64
12	2853.116	3.00	0.00	92.6	0.00	0.00	0.0	155.0	水平	10:08:44	1.65
13	3138.428	3.00	0.00	90.5	0.00	0.00	0.0	155.0	水平	10:08:48	1.67
14	3452.271	3.00	0.00	89.1	0.00	0.00	0.0	155.0	水平	10:08:51	0.09
15	3797.498	3.00	0.00	87.8	0.00	0.00	0.0	155.0	水平	10:08:55	0.09
16	4177.248	3.00	0.00	88.0	0.00	0.00	0.0	155.0	水平	10:08:59	0.00
17	4594.973	3.00	0.00	89.5	0.00	0.00	0.0	155.0	水平	10:09:03	1.66
18	5054.47	3.00	0.00	90.1	0.00	0.00	0.0	155.0	水平	10:09:06	1.65
19	5560.917	3.00	0.00	89.7	0.00	0.00	0.0	155.0	水平	10:09:10	0.00
									水平	10:09:14	0.00
									水平	10:09:18	0.00
									水平	10:09:22	1.65
									水平	10:09:25	1.65

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Recorded data -2-

- Save the image data
  - Save an image of “fail” situation
  - <File name>
  - yyyymmdd_hhmmss_(frequency)_(Modulation)_(Polarization).jpg

Recorded data -3-

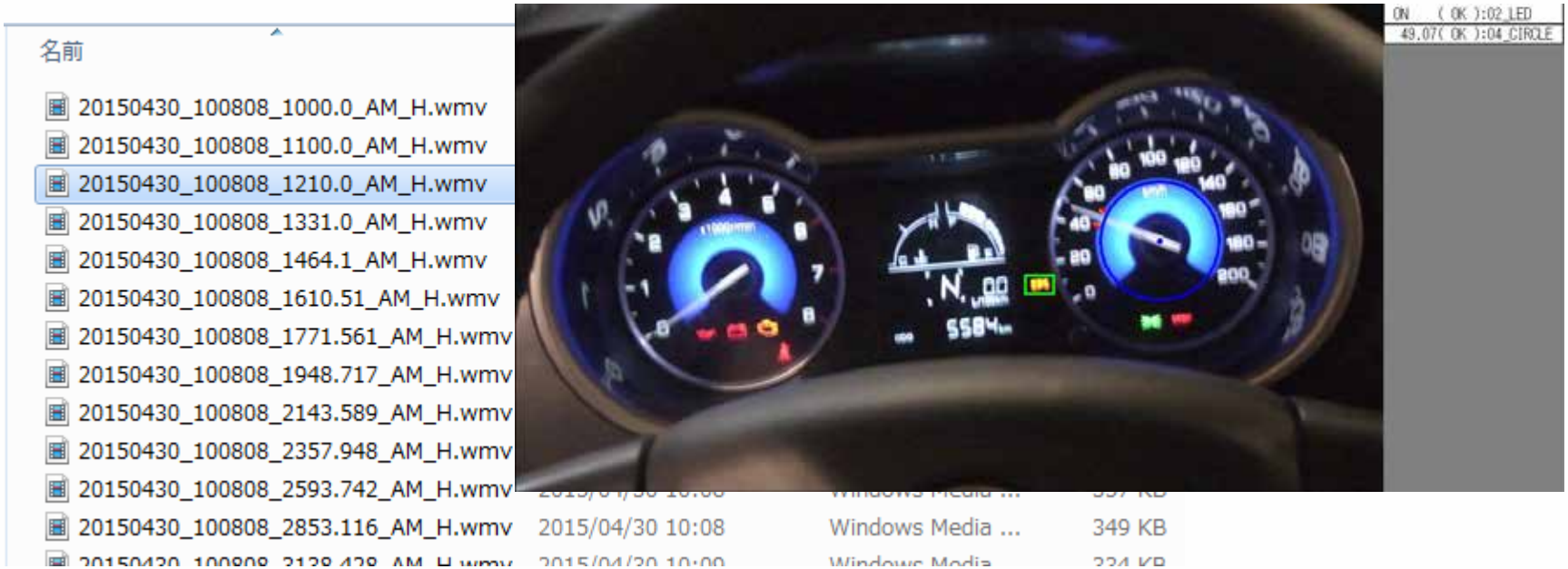
- Save the video data

  Save the video of entire test duration or only fault situation

  <File name>

  yyyymmdd_hhmmss_(frequency)_(Modulation)_(polarization).wmv

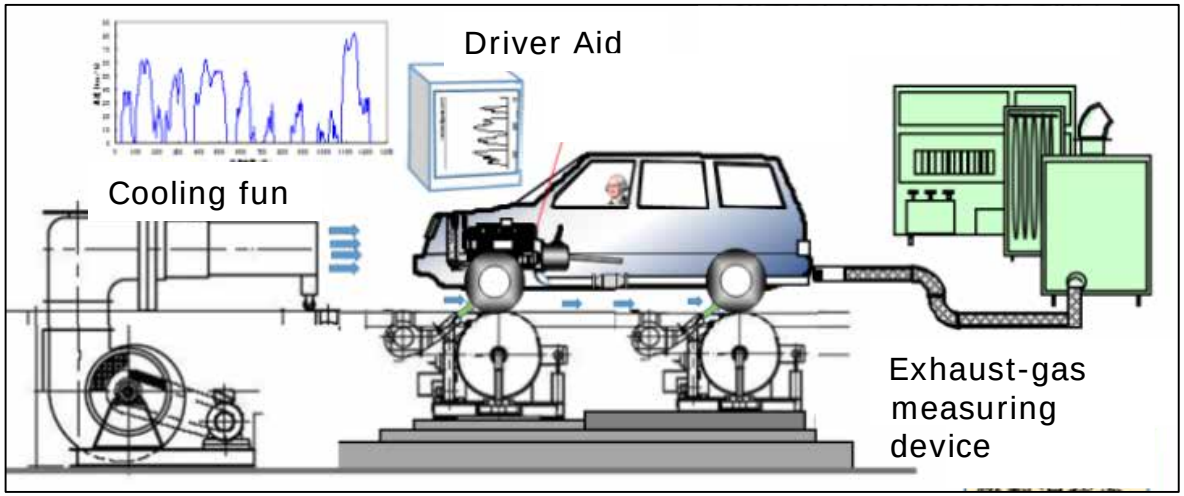
  Save for each frequency, modulation and polarization



New dynamometer -Current situation-

- Vehicle is tested while driving a car on a chassis dynamometer embedded in the basement of chamber.

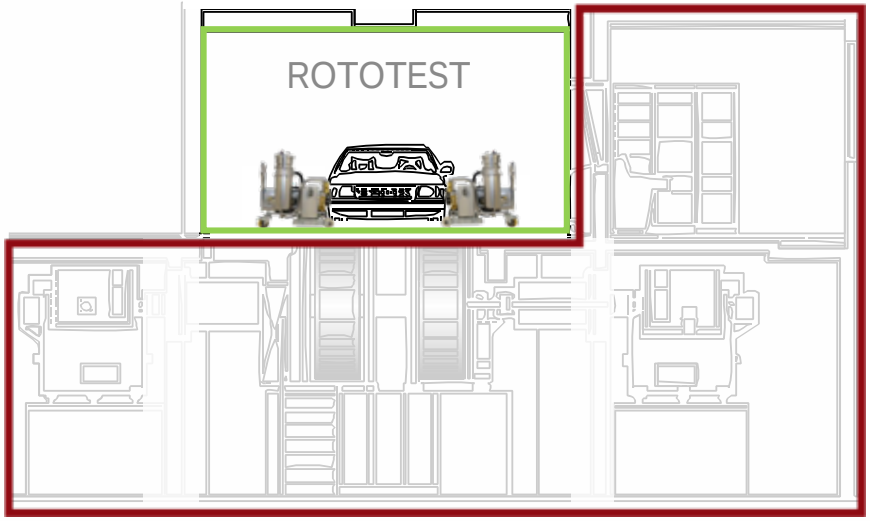
- Embedded chassis dynamometer needs a huge cost.
- Difficult to add the chassis dynamometer to the existing chamber.
- It's not possible to steer a car



New dynamometer -New proposal-

Rototest

- Space saving of equipment
- Construction cost reduction



p **Comparison with roller type**

ü There is no pit
(reduction of construction cost)

ü Can be installed in existing environmental room and anechoic chamber

ü Constitution installed even on the second floor

Easy to install

Competitive similar system

p **Comparison with other company's system**

ü Easy to install

ü It is possible to steer

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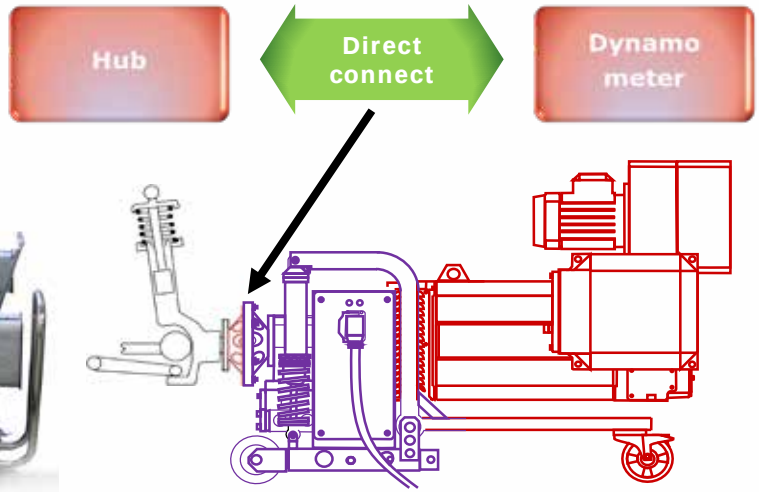
What will change?

Rototest

- Connect dynamometer to hub

- It is possible to turn steering.



Summary

- ***Part 1***
- ECE-R 10 added the EV / PHEV test item in the latest version
- Since EV / PHEV is connected to AC power supply during charging, CE(Conducted Emission) measurement is added
- The CE measurement of the communication line is complicated, such as considering LCL, but the target communication line is limited

- ***Part 2***
- EMC Test System
- Image processing system
- New dynamometer

Bibliography:

- ECE R10 Edtion3 , ECE R10 Edtion4 , ECE R10 Edtion5
- CISPR22 Edition6
- CISPR25 Edition4
- CISPR16-1-1(Ed.3) , CISPR16-1-2(Ed.2) , CISPR16-2-1(Ed.2)
- ”Vehicle EMC & ECE R10-03” JASIC W/G Mr. Nojima , Mr. Sakakibara
- E-Drive Testing Solution by Frankonia

Thank you for your attention.

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