Demystifying EMC 2023 Taiwan

SATELLITE EMC TESTING

DEMC GLOBAL TOUR

Daniel Loo
Technical Sales
Automotive and Military EMC Test system

ROHDE&SCHWARZ
Make ideas real

COMPANY RESTRICTED

EMC STANDARDS BASED ON EUT

► Different Electronic Equipment require compliance to different Standards

Commercial Equipment:
- ISM Equipment
- Consumer Electronics Equipment
- IT / Household Equipment
- Lighting Equipment

Applicable Standards:
- CISPR 11 - 35
- IEC61000-X-X series
- Product Specific Standards

Military Equipment:
- Aircraft Equipment
- Ship & Submarine Equipment
- Land Based Equipment

Applicable Standards:
- Mil-Std 461
- Mil-Std 464C
- GJB151A/152A-97

Automotive Equipment:
- Control Equipment
- Infotainment Equipment
- Communication Equipment

Applicable Standards:
- CISPR 12, 25
- ISO11451, ISO11452
- Product Specific Standards

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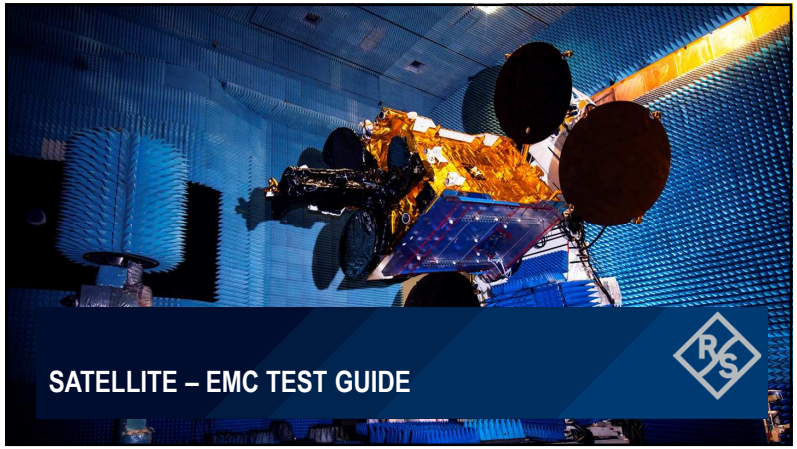
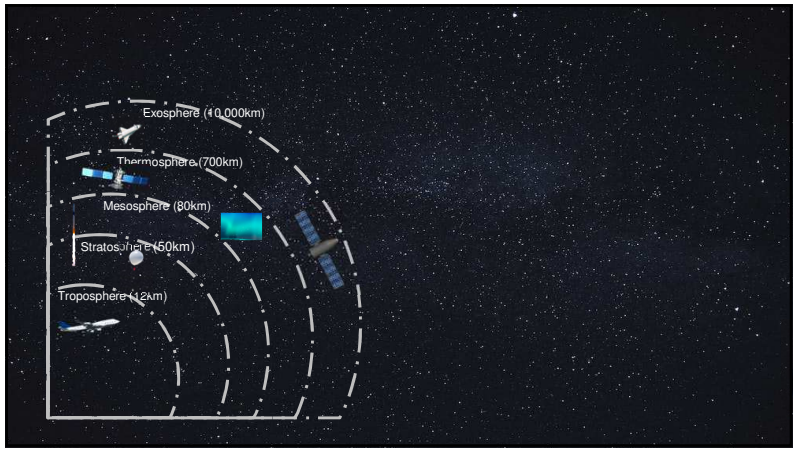
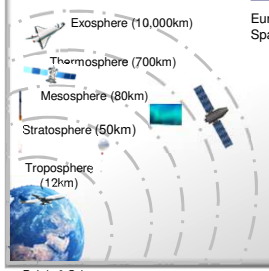




EMC STANDARDS BASED ON EUT

- Different Standards and EUT are drafted based on operating environment



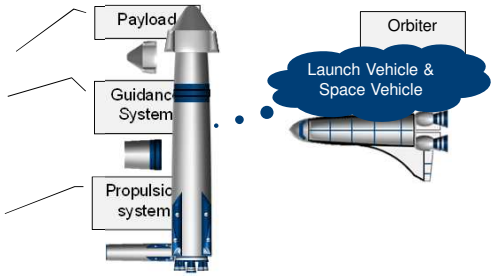
ECSS
European Cooperation for Space Standardization

NASA
Goddard Space Flight Center

AIAA
SHAPING THE FUTURE OF AEROSPACE
American Institute of Aeronautics and Astronautics

USA Department of Defense

PARTS OF SATELLITE ROCKET

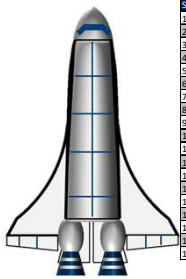


https://www.pngkey.com/detail/u2q8q8r5q8a9w7u2_rocket-vehicle-space-rocket-clip-art/

PURPOSE

- Ensuring space systems system level electromagnetic compatibility (EMC),for all Intersystem and Intra-system including all electromagnetic environmental effects.
- Guidelines for environmental verification programs for payloads, subsystems and components. Through baseline test and/or analysis and that minimum workmanship standards have been met.
- Gives guideline test levels, provides guidance in the choice of test options, and describes acceptable test and analytical methods for implementing the requirements.

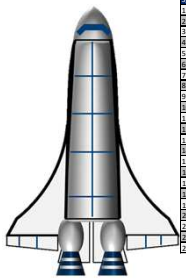
MIL-STD461G APPLICABLE TO SPACE SYSTEMS



MIL-STD 461 G

S/N	Requirement	Description	Frequency	Space System Applicability
1	CE101	Conducted Emissions, Audio Frequency Currents, Power Leads	30Hz to 10kHz	-
2	CE102	Conducted Emissions, Radio Frequency Potentials, Power Leads	10kHz to 10MHz	A
3	CE106	Conducted Emissions, Antenna Port	10kHz to 40GHz	L
4	CS101	Conducted Susceptibility, Power Leads	30Hz to 150kHz	A
5	CS103	Conducted Susceptibility, Antenna Port, Intermodulation	15kHz to 10GHz	S
6	CS104	Conducted Susceptibility, Antenna Port, Rejection of Undesired Signals	30Hz to 20GHz	S
7	CS105	Conducted Susceptibility, Antenna Port, Cross-Modulation	30Hz to 20GHz	S
8	CS109	Conducted Susceptibility, Structure Current	60Hz to 100kHz	-
9	CS114	Conducted Susceptibility, Bulk Cable Injection	10kHz to 200MHz	A
10	CS115	Conducted Susceptibility, Bulk Cable Injection, Impulse Excitation	Impulse Excitation	A
11	CS116	Conducted Susceptibility, Damped Sinusoidal Transients, Cables and Power Leads	Transient	A
12	CS117	Conducted Susceptibility, Lightning Induced Transients, Cables and Power Leads	Transient	L
13	CS118	Conducted Susceptibility, Personnel Borne Electrostatic Discharge	Transient	-
14	RE101	Radiated Emissions, Magnetic Field	30Hz to 100kHz	-
15	RE102	Radiated Emissions, Electric Field	10kHz - 18GHz	A
16	RE103	Radiated Emissions, Antenna Spurious and Harmonic Outputs	10kHz - 40GHz	L
17	RS101	Radiated Susceptibility, Magnetic Field	30Hz to 100kHz	-
18	RS103	Radiated Susceptibility, Electric Field	2MHz - 40GHz	A
19	RS105	Radiated Susceptibility, Transient Electromagnetic Field	Transient	-

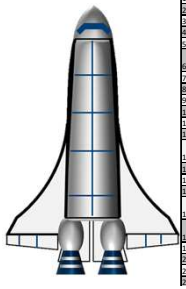
AIAA APPLICABLE TO SPACE SYSTEMS (EMC)



AIAA (Table 6Requirement Applicability Matrix)

S/N	Requirement	Description	Frequency	Launch Vehicle	Space Vehicle systems and subsystems	Ground Equipment
1	8.4.1	Power Bus conducted Interference , load induced, audio frequency	30Hz - 150kHz	A	A	S
2	8.4.2	Power Bus conducted Interference , load induced, audio frequency	150kHz - 20MHz	A	A	S
3	8.5	RF common mode conducted emissions, power and signal cables	150kHz - 20MHz	A	A	S
4	8.6	Conducted Emission, Antenna Terminal	10kHz - 40GHz	L	L	S
5	8.7	Conducted Emission, Differential Mode, Time Domain, Load Induced Voltage Transients	Transients	A	A	S
6	8.8	Audio Frequency Conducted Susceptibility, Power leads	30Hz - 150kHz	A	A	S
7	8.9	Audio Frequency Conducted Susceptibility, Antenna Port, Intermodulation	15kHz - 10GHz	S	S	S
8	8.10	Conducted Susceptibility, Antenna Port, Rejection of undesired Signals	30Hz - 20GHz	S	S	S
9	8.11	Conducted Susceptibility, Antenna Port, Cross-Modulation	30Hz - 20GHz	S	S	S
10	8.12	Conducted Susceptibility, Bulk Current Injection, Swept Frequency	10kHz - 200MHz	A	A	S
11	8.13	Conducted Susceptibility, Bulk Current Injection, Excitation	Impulses	S	S	S
12	8.14	Conducted Susceptibility, Damped Sinusoidal Transients	10kHz - 100MHz	A	A	S
13	8.15	Conducted Susceptibility, Ground Plane Injection Spike	Spikes	A	A	S
14	8.16	Conducted Susceptibility, Ground Plane Injection, Audio Frequency	30Hz - 150kHz	A	A	S
15	8.17	Conducted Susceptibility, Ground Plane Injection, Radio Frequency	150kHz - 100MHz	A	A	S
16	8.18	Susceptibility to switching Transients, Power leads, Time Domain	Transients	A	A	S
17	8.19	Radiated Emission, Magnetic Field	30Hz - 100kHz	S	S	S
18	8.20	Radiated Emission, Electric Field	20MHz - 18GHz	A	A	S
19	8.21	Radiated Susceptibility, Magnetic Field	30Hz - 100kHz	L	L	S
20	8.22	Radiated Susceptibility, Electric Field	2MHz - 18GHz	S	S	S
21	8.23	Radiated Emission, Magnetic Field	30Hz - 100kHz	A	A	S
22	8.24	Conducted Susceptibility, Lightning Induced Transients, cables and power leads	Transients	L	L	S
23	8.25	Electrostatic Discharge Susceptibility, Personnel Borne	Transients	L	L	S

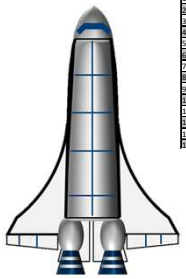
GSFC APPLICABLE TO SPACE SYSTEMS (EMC)



GSFC (Table 2.5-2, EMI Requirements Summary)

S/N	Requirement	Description	Frequency	Limits	Test Methods
1	CE101	Conducted Emissions, Audio Frequency Currents, Power Leads	30Hz to 10kHz	Tailored	DM
2	CE102	Conducted Emissions, Radio Frequency Potentials, Power Leads	10kHz to 10MHz	Tailored	CE03, DM, MIL462
3	**NEW**	Conducted Emissions, Common Mode Power and Signal Lines	10kHz -200MHz	NEW	NEW
4	**NEW**	Conducted Emissions, Turn-on Transient	Transients	NEW	NEW
5	CE106	Conducted Emissions, Antenna Terminal	200MHz - 18GHz (a)	Tailored	No Change
6	CS101	Conducted Susceptibility, Power Leads	30Hz to 150kHz	Tailored	Alt. Test method available
7	CS103	Conducted Susceptibility, Antenna Port, Intermodulation	15kHz to 10GHz (b)	Tailored	No Change
8	CS104	Conducted Susceptibility, Antenna Port, Rejection of Undesired Signals	30Hz to 20GHz (b)	Tailored	No Change
9	CS105	Conducted Susceptibility, Antenna Port, Cross-Modulation	30Hz to 20GHz	N/A	N/A
10	**CS06**	Conducted Susceptibility, Transients, Power Leads	Transients	CS06	CS06, MIL462
11	CS109	Conducted Susceptibility, Structure Current	60Hz to 100kHz	N/A	N/A
12	CS114	Conducted Susceptibility, Bulk Cable Injection	10kHz to 200MHz	Tailored	No Change
13	CS115	Conducted Susceptibility, Bulk Cable Injection, Impulse Excitation	Impulse Excitation	No Change, Applicable	No Change, Applicable
14	CS116	Conducted Susceptibility, Damped Sinusoidal Transients, Cables and Power Leads	Transient	Applied case by case	Applied case by case
15	CS117	Conducted Susceptibility, Lightning Induced Transients, Cables and Power Leads	Transient	Applied case by case	Applied case by case
16	CS118	Conducted Susceptibility, Personnel Borne Electrostatic Discharge	Transient	Applied case by case	Applied case by case
17	RE101	Radiated Emissions, Magnetic Field	30Hz to 100kHz	Tailored	Alt. RE04, MIL462 available.
18	RE102	Radiated Emissions, Electric Field	10kHz - 18GHz	Tailored	Alt. Test method available
19	RE103	Radiated Emissions, Antenna Spurious and Harmonic Outputs	10kHz - 40GHz	N/A	N/A
20	RS101	Radiated Susceptibility, Magnetic Field	30Hz to 100kHz	Tailored	No Change
21	RS103	Radiated Susceptibility, Electric Field	2MHz - 40GHz	Tailored	Tailored
22	RS105	Radiated Susceptibility, Transient Electromagnetic Field	Transient	N/A	N/A

ECSS APPLICABLE TO SPACE SYSTEMS (EMC)



ECSS (Table 5-4 Correspondence between Test procedures and limits)

S/N	Requirement	Description	Frequency	
1	A.2	CE on power leads, differential mode (Part 1)	30Hz - 100kHz	Limit and Test method provided
2	A.2	CE on power leads, differential mode (Part 2)	100kHz - 100 MHz	Limit provided, Test method Ref. to A.4
3	A.3	CE on power leads, in-rush currents	Transients	Limit and Test method provided
4	A.4	CE on power and signal leads, common mode	100kHz - 100 MHz	Limit and Test method provided
5	A.6	DC Magnetic field emission	Transients	NEW
6	A.7	RE, low frequency Magnetic field	Specific	Analysis needed
7	A.8	RE, low frequency Electric field	Specific	Analysis needed
8	A.9	RE, Electric Field	30MHz - 18GHz	Limit provided. Setup: RE102
9	A.10	CS, power leads, differential mode	30Hz - 100kHz	Limit and Test method provided
10	A.11	CS, power and signal leads, common mode	50kHz - 100MHz	Limit and Test method provided
11	A.12	CS, power leads, short spike transients	Transients	Limit and Test method provided
12	A.13	RS, Magnetic field	30Hz - 100kHz	Immunity level provided. Setup: RS101
13	A.14	RS, Electric Fields	30MHz - 18GHz	Immunity level provided. Setup: RS103
14	A.15	Susceptibility to Electrostatic Discharge (Legacy method)	Transients	Legacy and Alternate method specified.

ECSS APPLICABLE TO SPACE SYSTEMS (EMI)

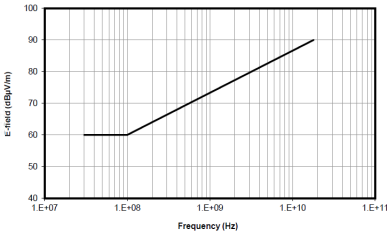


Figure A-3: Radiated electric field limit

ECSS TABLE 5-2. Bandwidth and Measurement time			
Frequency Range (Hz)	6dB BW (Hz)	Min. Dwell time Receiver (S)	Min. Measurement Time Analog-Tuned
30-1k	10	0.15	0.015sec/Hz
1k-10k	100	0.015	0.15sec/kHz
10k-150k	1k	0.015	0.015sec/kHz
150k-30M	10k	0.015	1.5sec/MHz
30M-1G	100k	0.015	0.1sec/MHz
Above 1G	1M	0.015	15sec/GHz

- Bandwidth and measurement time is with reference to MIL461E section 4.3.10.3.1-Table 2
- Video filtering shall not be used to bandwidth limit the receiver response. If is available on the measurement receiver, it shall be set to its greatest value. (Such requirement are not stated in AIAA and GSFC).
- Peak detections, 200MHz – 18GHz
- Set-up and testing in accordance to MIL-STD-461G

AIAA APPLICABLE TO SPACE SYSTEMS (EMS)

AIAA TABLE 2. Ground operations through launch SV/LV separation		
Frequency Range (Hz)	Environment Level V/m (Peak)	Modulation
2M - 18G	20	Pulse Modulated (on/off ratio of 40 dB minimum) 1 kHz rate with a 50% duty cycle
18G - 40G (Required only if specified in procurement Spec)	20	CW (no modulation) Pulse Modulated 1 kHz rate with a 1 µs pulse width
2G - 2.5G	100	CW (no modulation)
5.4G - 5.9G	100	Pulse Modulated (on/off ratio of 40 dB minimum) 1 kHz rate with a 1 µs pulse width

AIAA TABLE 3. On-Orbit		
Frequency Range (Hz)	Environment Level V/m (Peak)	Modulation
2M - 18G	20	Pulse Modulated (on/off ratio of 40 dB minimum) 1 kHz rate with a 50% duty cycle
18G - 40G (Required only if specified in procurement Spec)	20	CW (no modulation) Pulse Modulated 1 kHz rate with a 1 µs pulse width
2G - 2.5G	50	CW (no modulation)
5.4G - 5.9G	50	Pulse Modulated (on/off ratio of 40 dB minimum) 1 kHz rate with a 1 µs pulse width

AIAA (MIL-STD-461G) TABLE III. Susceptibility scanning		
Frequency Range (Hz)	Analog Scans Maximum Scan Rates (fo/sec)	Stepped Scans Max Step Size (fo)
30 - 1M	0.0333	0.05
1M - 30M	0.00667	0.01
30M - 1G	0.00333	0.005
1G-40G	0.00167	0.0025

GSFC APPLICABLE TO SPACE SYSTEMS (EMS)

GSFC Radiated Susceptibility, Electric Field			
Frequency Range (Hz)	Environment Level V/m (Peak)	Modulation	Remarks
2M - 18G	20	Pulse Modulated (on/off ratio of 40 dB minimum) 1 kHz rate with a 50% duty cycle	Equipment that will be on during launch.
2M - 18G	2	Pulse Modulated (on/off ratio of 40 dB minimum) 1 kHz rate with a 50% duty cycle	Equipment that will be off during launch. Min. on orbit environment.

GSFC Table 2.5-1. Susceptibility Scanning (Replacement for MIL-STD-461G Table III)		
Frequency Range (Hz)	Analog Scans Maximum Scan Rates (fo/sec)	Stepped Scans Max Step Size (fo)
30 - 1M	0.0333	0.05
1M - 30M	0.00667	0.01
30M - 1G	0.00333	0.005
1G-18G	0.00167	0.01

ECSS APPLICABLE TO SPACE SYSTEMS (EMS)

ECSS Table 5-3. Susceptibility Scanning (Replacement for MIL-STD-461G Table III)			
Frequency Range (Hz)	V/m (Peak)	Modulation	Remarks
30M-18G	10	Pulse Modulated (on/off ratio of 40 dB minimum) 1 kHz rate with a 50% duty cycle	Equipment in the vicinity of transmission beams, outside of the main frame
30M-18G	1	Pulse Modulated (on/off ratio of 40 dB minimum) 1 kHz rate with a 50% duty cycle	Equipment far from main lobes and secondary lobes, outside of the main frame
30M-18G	1	Pulse Modulated (on/off ratio of 40 dB minimum) 1 kHz rate with a 50% duty cycle	Equipment inside the main frame

ECSS Table 5-3. Susceptibility Scanning	
Frequency Range (Hz)	Stepped Scans Max Step Size (fo)
30-100k	0.05
100k-1M	0.05
1M-10M	0.02
10M-50M	0.02
50M-200M	0.01
200M-1G	0.01
1G-18G	0.01

ELECTROMAGNETIC ENVIRONMENT EFFECTS

IN THE A&D DOMAIN EMC TESTS ARE SUMMARIZED AS E3

- ► Beside Standard EMC testing, there are RF Spectrum Measurement for Transmitters which installed on System.
- ► Some existing EMC customers had planned and enquired to extend their existing EMC test system (base on Mil-std-461) specifications and capabilities to meet E3 test requirements.
- ► Such as System Level NEMP, ESD, HIRF, HERO, HERP, PIM, Transmitter and Receiver Performance, Antenna Radiation Patterns. etc… measurements

THE IMPORTANCE OF SYSTEM LEVEL EME EFFECTS TEST

What are the differences ?

Standard EMC Test

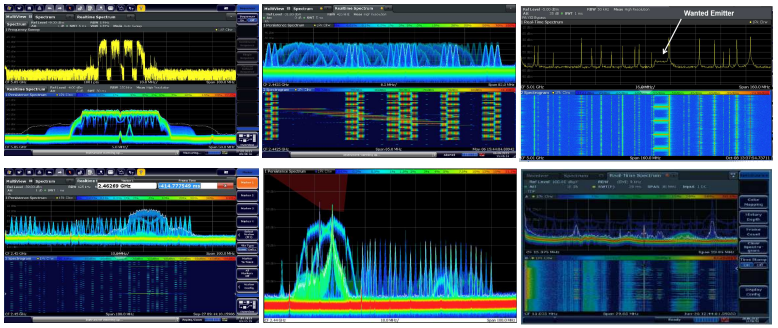
- **Operate according to requirements (Fix environment)**
- **Frequency domain**
- **Research and design work**
- **According to test methods**

System Level

- **Operational environmental conditions (no definition!)**
- **Analysis of EM interference**
- **Time and frequency domain**
- **In launch and space condition with critical limits varies**

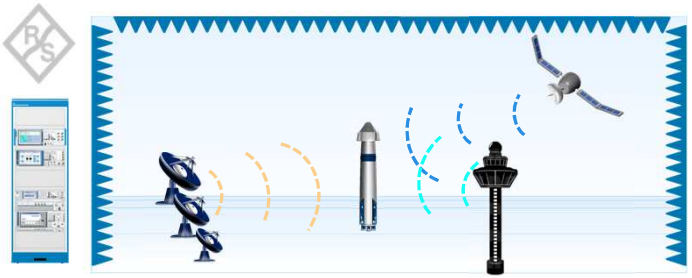
EME EFFECTS TESTING IN THE CHAMBER

Autonomous, EME Complexity, Coexistence and Connectivity



EME EFFECTS TESTING IN THE CHAMBER

Autonomous, EME Complexity, Coexistence and Connectivity are in futuristic battlefield



E3-MARGIN

1.Establish the external threat environment against which the system is required to demonstrate compliance of immunity.

2.Identify the system electrical and electronic equipment performing functions required for operation during application of the external threat.

3.Establish the internal environment caused by external electromagnetic effects for each installed equipment.

4.Design the system and equipment protection.

5.Verify the protection adequacy, typically require an overall margin of 6 dB (16.5dB for EIDs).

Demystifying EMC 2023 virtual conference

SATELLITE EMC TESTING

q&a

Thank you for listening.

For any questions please contact us via chat.

ROHDE&SCHWARZ
Make ideas real

Progress in EMC standardization

CISPR 16-1-1

Jens Medler

ROHDE&SCHWARZ
Make ideas real

CISPR | International special committee on radio interference | Comité international spécial des perturbations radioélectriques

- Technical committee within the International Electrotechnical Commission (IEC)
- The committee is constituted of 7 sub-committees that fulfil both product (vertical) and basic (horizontal) standardisation roles
- CISPR was established in 1933 and had its first meeting in June 1934 in Paris, with representatives of 6 national committees of the IEC (Belgium, The Netherlands, Luxembourg, France, Germany and UK)
- Today CISPR one of 110 technical committees of IEC
- Members of CISPR are 41 National Committees (24 participate / 17 observer), EBU, ETSI, CIGRE, IARU and both ITU-R and ITU-T

WAS ESTABLISHED TO CONSIDER THE PROTECTION OF RADIO RECEPTION FROM INTERFERENCE

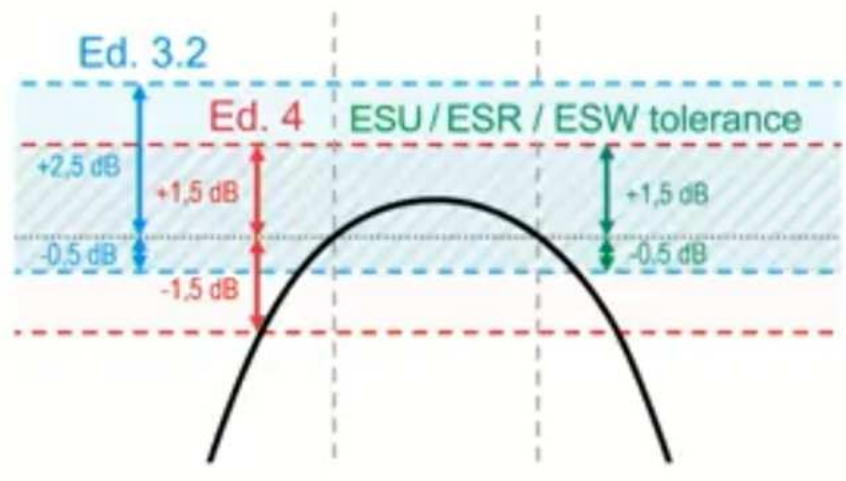
CISPR 16 – CISPR-AVERAGE DETECTOR

- **Amendment A1: 2002 to CISPR 16-1:1999 (2nd Edition)**
  - **Adds The requirements for the linear average detector with meter time constant**
  - **R&S measuring receivers are using the acronym “CAV” (spell “CISPR-AV”) in contract to “AV” for the true average detector.**
  - **CAV detector need to be used for testing against AV limits in CISPR standard!**

CISPR 16 – CISPR-AVERAGE DETECTOR

➢ Pulse amplitude relationship for average detector

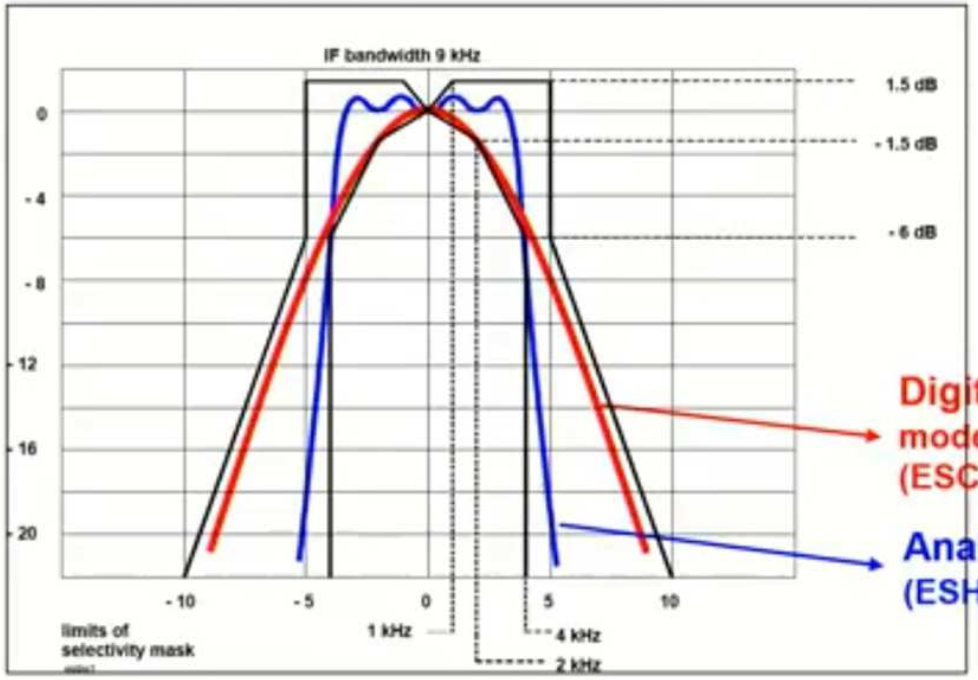
- **A tolerance of 1.5dB/-1.5dB is permitted**



R&S® ESW, R&S® ESR and R&S® ESU are calibrated to a tolerance of -0.5dB/+1.5dB to comply with both CISPR 16-1-1:2004 (Ed.3.2) and CISPR 16-1-1:2015 (Ed.4) as common tolerance of both requirements.

CISPR 16 – NEW REQUIREMENTS IN ED.4/ED.5

- **Justification for the symmetric tolerance – use of Gaussian filters**



Digital Gauss Filter:
modern receivers and analyzers
(ESCI, ESU, ESR, ESRP, ESW)

Analog Tschebyscheff Filter:
(ESH3, ESVP, ESIB)

CISPR 16 – NEW REQUIREMENTS IN ED.5

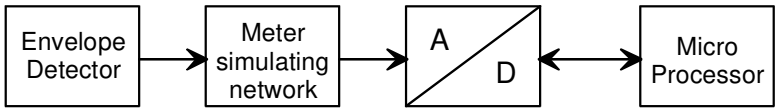
➢ Publication status and Applicability

CISPR 16-1-1:2014 ED3.2	CISPR 16-1-1:2015 ED4	CISPR 16-1-1:2019 ED5
CISPR 11:2015 (ED6)	CISPR 14:2016 (ED6) CISPR 14:2020 (ED7)	IEC 61000-6-3:2020
CISPR 12:2007 (ED6) refers to 16-1-1:2006	CISPR 15:2018 (ED9)	IEC 61000-6-8:2020
	CISPR 25:2016 (ED4)	CISPR 25:2021 (ED5)
ANSI C63.2:2016 / FCC	CISPR 32:2019 (ED2.1)	
	CISPR 36:2020 (ED1)	
	IEC 61000-6-4:2018	

CISPR 16 – CISPR-AVERAGE DETECTOR

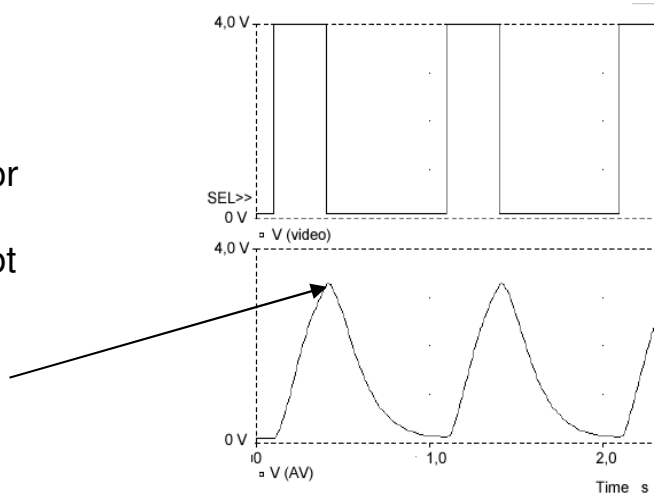
Linear CISPR-Average detector with meter time constant

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



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

but the maximum of the output of the meter simulating network

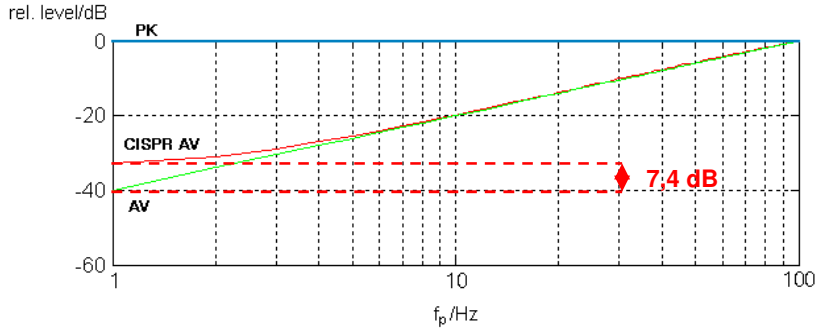


CISPR 16 – CISPR-AVERAGE DETECTOR

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

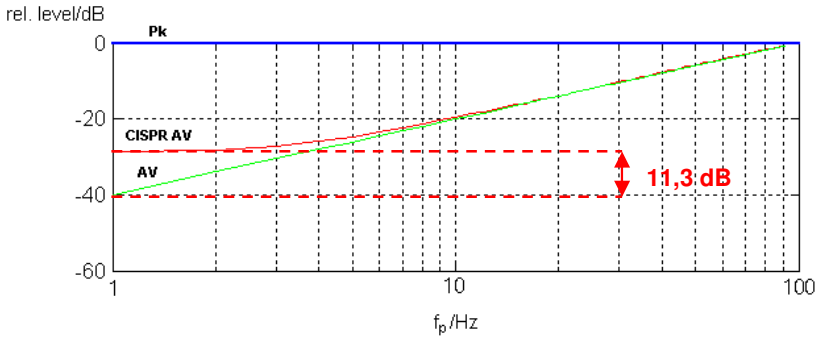
Band A/B:

T_{meter} = 160 ms



Band C/D/E:

T_{meter} = 100 ms



CISPR 16 – FFT-BASED MEASURING RECEIVERS

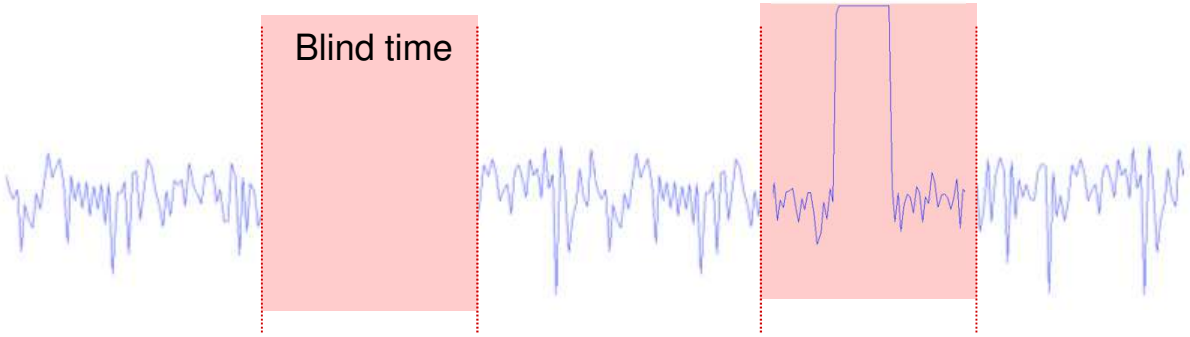
More Speed with Time-Domain Scan

Measurement Times	R&S ESW		
	Stepped Scan	Auto TDS (Full compliant)	Fast TDS (PRF 10 Hz)
150 kHz – 30 MHz 9 kHz, Peak, 100 ms	**12:35 min**	**0.11 s**	**0.11 s**
150 kHz – 30 MHz 9 kHz, **QP + CAV**, 1 s	**~ 3.8 h**	**2 s**	**2 s**
30 MHz – 1000 MHz 120 kHz, Peak, 10 ms	**4:15 min**	**0.38 s**	**0.38 s**
30 MHz – 1000 MHz 120 kHz, **QP + CAV**, 1 s	**~ 10 h**	**50 s**	**40 s**

CISPR 16 – FFT-BASED MEASURING RECEIVERS

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

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



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

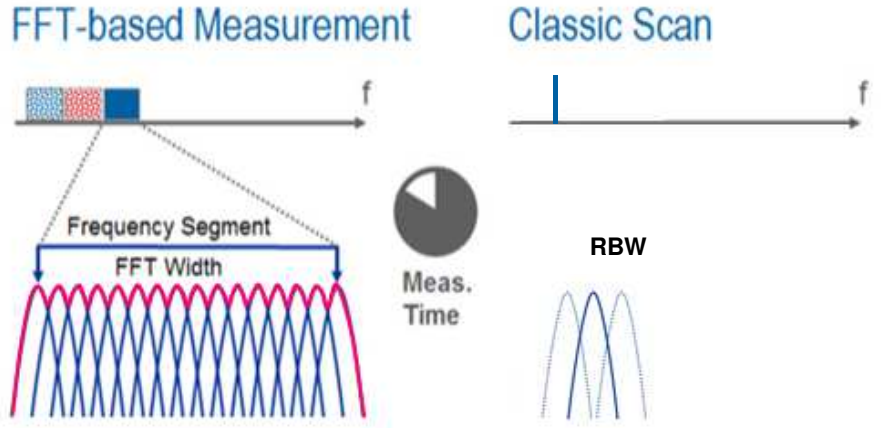
CISPR 16 – FFT-BASED MEASURING RECEIVERS

Motivation for FFT-based measurement instrumentation

- **More Speed – FFT-based receivers are measuring spectral segments much wider than the resolution bandwidth during the measurement time by parallel calculation at several frequencies**

- **More Reliable – FFT allows application of longer measurement times, e.g. for measuring intermittent signals**

- **More Insight – FFT makes enhanced measurement functions like scan spectrogram and persistence display applicable**



Ultra-fast scan time for entire frequency range

Long scan time for entire frequency range