

EMC TESTING FUNDAMENTALS

ROHDE & SCHWARZ

Make ideas real



COMPANY RESTRICTED

OUTLINE

- ▶ What is EMC Testing
- ▶ Who needs it and what drives it?
- ▶ Test Types
 - Conducted
 - Emissions
 - Immunity
 - Radiated
 - Emissions
 - Immunity
- ▶ Pre-Compliance Testing
- ▶ Full Compliance Testing
- ▶ Demo

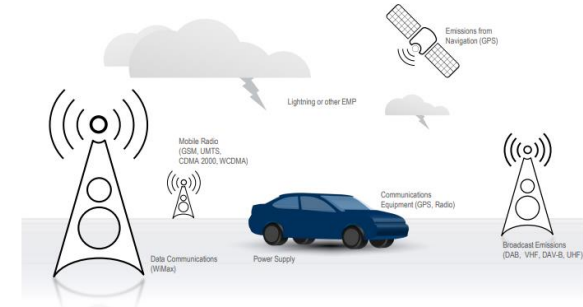


WHAT IS EMC TESTING?

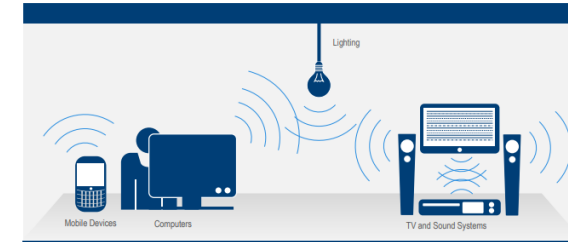
What is EMC?

- ▶ Electromagnetic compatibility (EMC) is an important criteria of product safety and quality. **Every electrical device has to fulfill Electromagnetic compatibility (EMC) requirements by law.** It is mandatory in the product certification process.
- ▶ The equipment under test “EUT” can have anomalies caused by **external impacts** (RF or electrical disturbances in close proximity to the “EUT”), **internal impacts** (emissions from components) or human interaction (i.e. ESD) and must be tested to avoid potential failures.
- ▶ Electromagnetic compatibility (EMC) is the **capability** of an electrical device or system **to operate** in its electromagnetic environment **without either**
 - **disturbing it** (i.e. producing emissions or interference = EMI) OR
 - **being disturbed by it** (i.e. susceptibility = immunity = EMS)
 - **EMC = EMI + EMS**

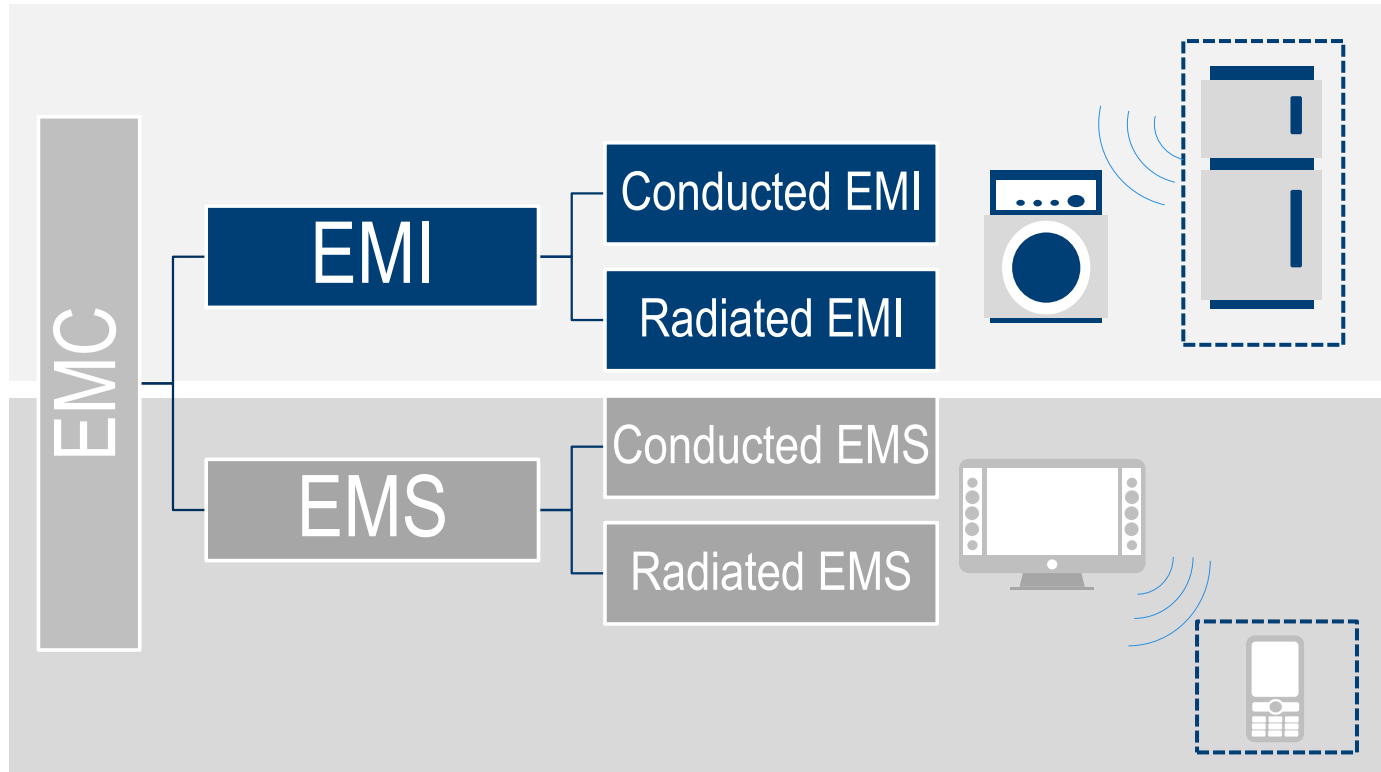
Outdoor Environment



Indoor Environment (Living Room)



EMC = EMI + EMS



WHO NEEDS IT?

Markings

- ▶ EMC is mandatory for all electronic products and is strictly regulated by development and production standards to ensure products' safe operation next to other electronic devices.
 - EMC is important in areas where precise tasks are carried out by mobile phones and computers, automated vehicles and aircraft, and where even slight disturbances might cause serious unforeseen consequences.
- ▶ The Conformité Européenne (CE) mark is one example of a certification mark. It indicates that a product meets all the standards and regulations required to be sold within the European Economic Area (EEA).
- ▶ UL (or others): Can it be plugged safely into an electric outlet?
- ▶ FCC: Does it not give off interference-causing EMF?



Item	Certificate Name	Area of application	Mandatory or Voluntary	Requirement
1	UL	United States	Voluntary	Safety
2	ETL	United States	Voluntary	Safety
3	FCC	United States	Mandatory	EMC
4	Energy Star	United States	Voluntary	Energy efficiency
5	CSA	Canada	Voluntary	Safety
6	CE	European Union	Mandatory	LVD and EMC tests
7	RoHS	European Union	Mandatory	Directive (EU) 2015/863
8	Ecodesign Directive	European Union	Mandatory	Directive 2009/125/EC
9	ErP	European Union	Voluntary	Energy efficiency
10	GS	Germany	Voluntary	Energy efficiency
11	VDE	Germany	Voluntary	Safety
12	BS	United Kingdom	Voluntary	ISO 9001 / ISO 14001 / ISO/IEC 27001
13	UKCA	United Kingdom	Mandatory	LVD and EMC tests
14	SAA	Australia	Mandatory	Safety
15	PSE	Japan	Mandatory	Safety and EMC
16	JIS	Japan	Voluntary	EMC
17	CCC	China	Mandatory	Safety
18	BIS	India	Mandatory	Safety
19	EAC	Russia	Mandatory	Safety
20	SABER	Saudi Arabia	Mandatory	Safety
21	SABS	South Africa	Voluntary	Safety
22	NOM	Mexico	Mandatory	Safety
23	INMETRO	Brazil	Mandatory	
24	CB	Worldwide	Voluntary	

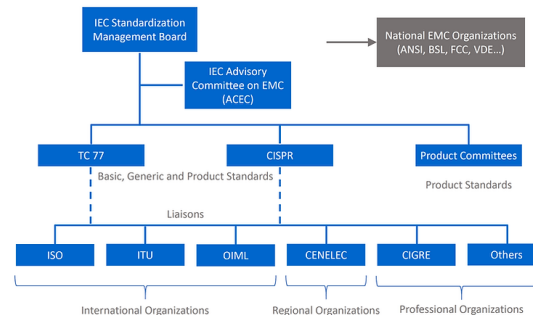
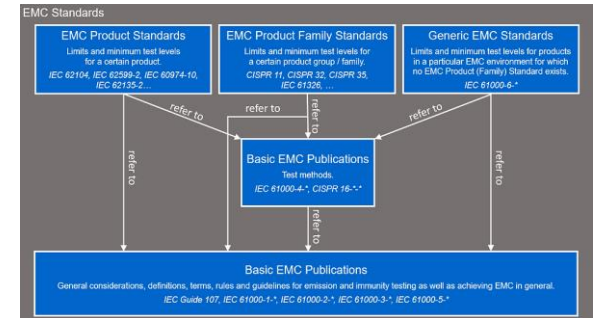
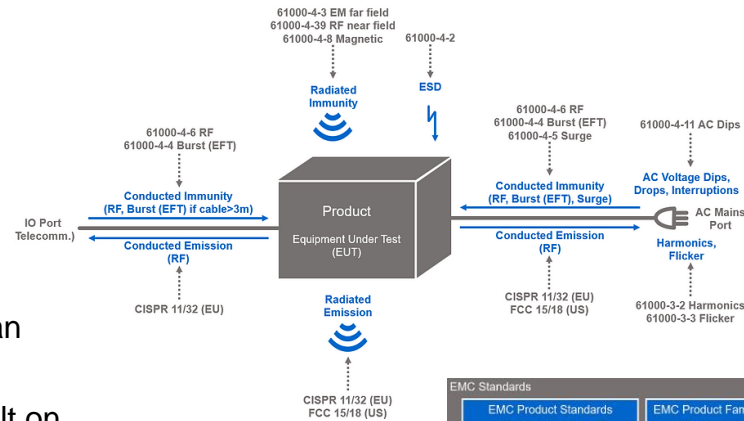
Compliance Vs. Certification

- ▶ Compliance
 - means that your product successfully complies with specific regulations and standards
- ▶ Certification
 - means that the product has been checked for compliance, either through authorized third-party testing organizations or, in some cases, "self-certified." Passing a certification includes permission to include the appropriate icons/graphics in your product packaging and elsewhere.
- ▶ Part of the challenge is to identify which certifications ones your product must satisfy?
 - This is governed by markets in which you wish to sell your product.

WHAT DRIVES IT?

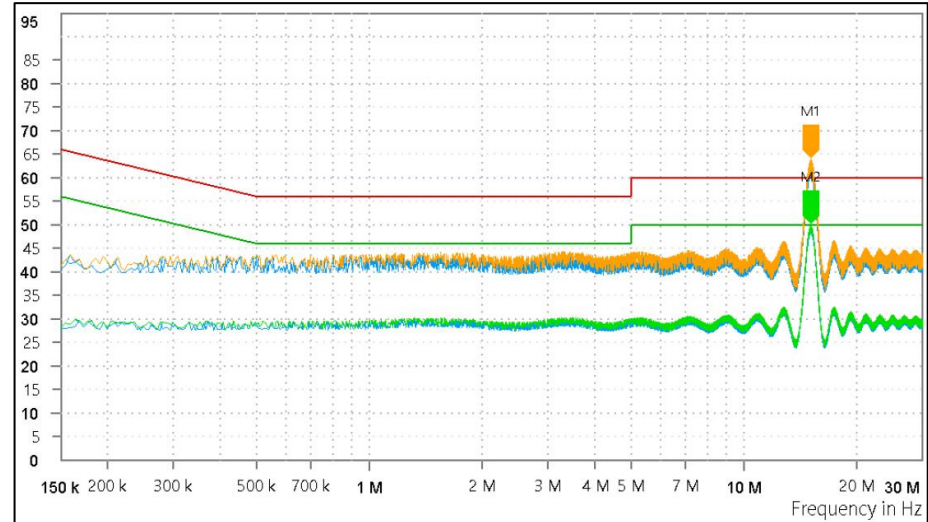
Standards

- ▶ Testing standards are used by scientists and professionals to ensure quality and consistency. Depending on the application, testing standards can either be mandatory or voluntary.
- ▶ A standardized test is a method of assessment built on the principle of consistency
- ▶ EMC standards define terms, rules, test methods, emission limits and immunity levels for Electromagnetic Compatibility
- ▶ EMC standards help to make measurements comparable and repeatable by defining the test methods, the test equipment and the test environment.



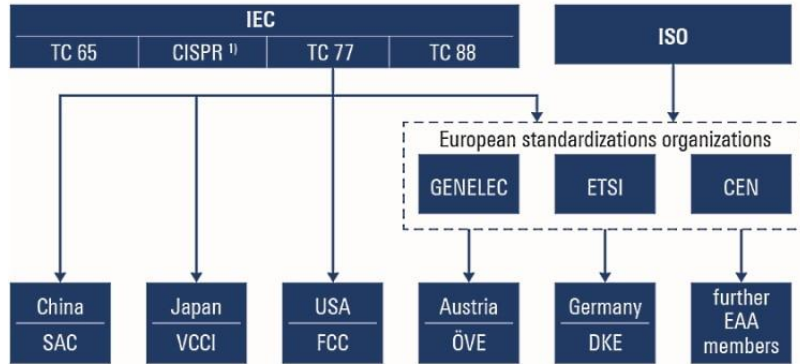
What are EMC standards?

- ▶ Ensure proper adherence to EMC requirements set by regulatory bodies
- ▶ Define acceptable emission and immunity levels
- ▶ Outline proper testing methodologies
- ▶ Aim of EMC is to ensure safety



Who defines EMC standards?

Commercial standardisation



- ▶ **IEC**
International Electrotechnical Commission
- ▶ **ISO**
International Organization for Standardization
- ▶ **CISPR**
International special committee on radio interference
- ▶ **CEN**
European Committee for Standardization
- ▶ **CENELEC**
European Committee for Electrotechnical Standardization
- ▶ **ETSI**
European Telecommunications Standards Institute

Commercial standards	CISPR	CENELEC (Europe)	FCC (USA)	METI (Japan)
Industrial, scientific and medical equipment	11	EN 55011	Part 18, C	J55011
Vehicles, boats and internal combustion engines	12/25	EN 55012 EN 55025	SAEJ551 J1113	JASO D001-82
Electrical devices, household appliances and tools	14-1	EN 55014-1	-	J55014-1
Electrical lightning	15	EN 55015	-	J55015
Multimedia equipment	32	EN 55032	Part 15, B	J55032
Military equipment	MIL-STD-461			
Aviation	DO-160			

EMC Standards Overview

► Different electronic equipment require compliance to different standards

Commercial Equipment:

- | ISM Equipment
- | Consumer Electronics Equipment
- | IT / Household Equipment
- | Lighting Equipment

Applicable Standards:

- | CISPR 11 to 35
- | IEC/EN61000-X-X series
- | Product Specific Standards

A&D Equipment:

- | Aircraft Equipment
- | Ship & Submarine Equipment
- | Land Based Equipment

Applicable Standards:

- | MIL-STD 461
- | MIL-STD 464
- | RTCA DO 160

Automotive Equipment:

- | Control Equipment
- | Infotainment Equipment
- | Communication Equipment

Applicable Standards:

- | CISPR 12, 25
- | ISO11451, ISO11452
- | Country-specific standards
- | OEM-specific standards

Medical Equipment:

- | Medical devices
- | Diagnostic machines
- | Hearing aids

Applicable Standards:

- | CISPR 11
- | IEC 60601-1-2 Ed. 4.0
- | IEC 61000-x-x



EMC Standards Overview

► Different electronic equipment require compliance to different standards

Commercial Equipment:

- | ISM Equipment
- | Consumer Electronics Equipment
- | IT / Household Equipment
- | Lighting Equipment

Applicable Standards:

- | CISPR 11 to 35
- | IEC/EN61000-X-X series
- | Product Specific Standards



A&D Equipment:

- | Aircraft Equipment
- | Ship & Submarine Equipment
- | Land Based Equipment

Applicable Standards:

- | MIL-STD 461
- | MIL-STD 464
- | RTCA DO 160



Automotive Equipment:

- | Control Equipment
- | Infotainment Equipment
- | Communication Equipment

Applicable Standards:

- | CISPR 12, 25
- | ISO11451, ISO11452
- | Country specific standards
- | OEM Specific Standards



Medical Equipment:

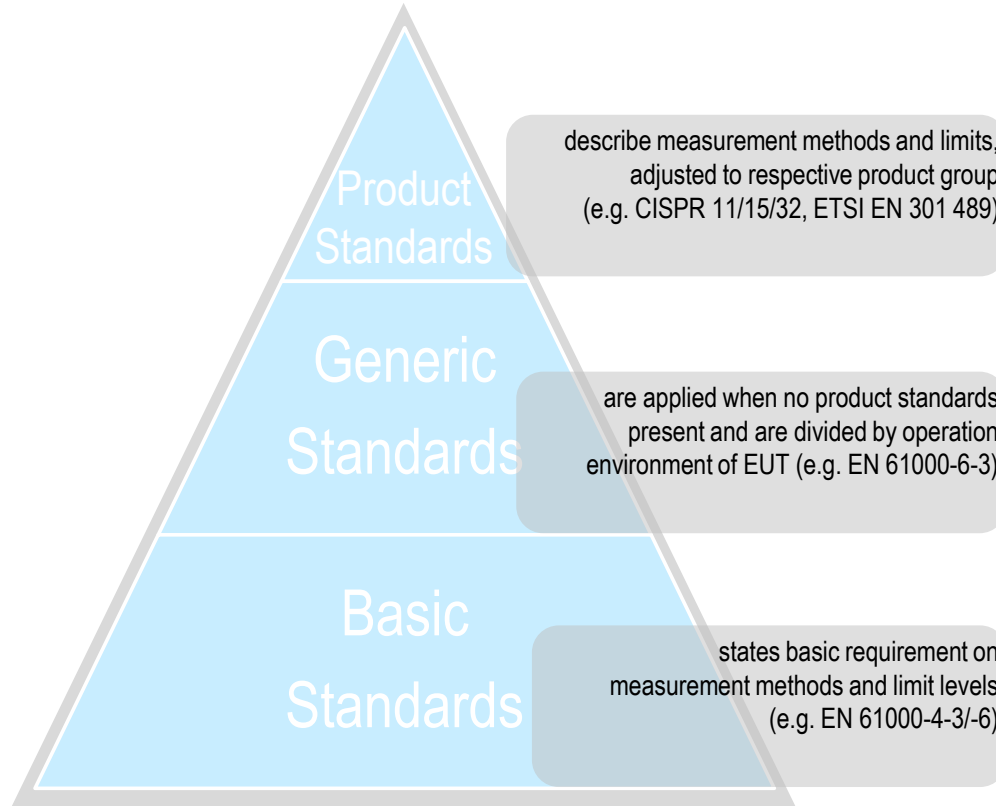
- | Medical devices
- | Diagnostic machines
- | Hearing aids

Applicable Standards:

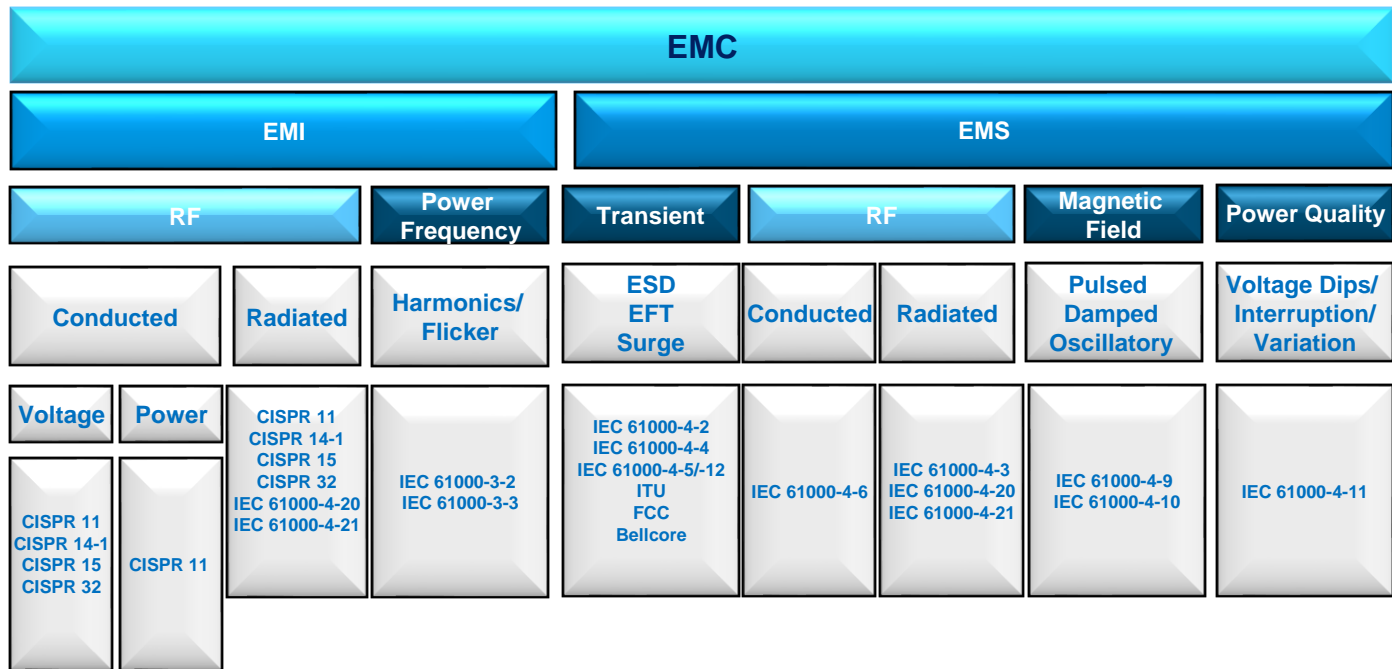
- | CISPR 11
- | IEC 60601-1-2 Ed. 4.0
- | IEC 61000-x-x



IEC, CISPR Publication Levels



EMC Standards for Commercial



EMC Standards Overview

► Different electronic equipment require compliance to different standards

Commercial Equipment:

- | ISM Equipment
- | Consumer Electronics Equipment
- | IT / Household Equipment
- | Lighting Equipment

Applicable Standards:

- | CISPR 11 to 35
- | IEC/EN61000-X-X series
- | Product Specific Standards

A&D Equipment:

- | Aircraft Equipment
- | Ship & Submarine Equipment
- | Land Based Equipment

Applicable Standards:

- | MIL-STD 461
- | MIL-STD 464
- | RTCA DO 160

Automotive Equipment:

- | Control Equipment
- | Infotainment Equipment
- | Communication Equipment

Applicable Standards:

- | CISPR 12, 25
- | ISO11451, ISO11452
- | Country specific standards
- | OEM Specific Standards

Medical Equipment:

- | Medical devices
- | Diagnostic machines
- | Hearing aids

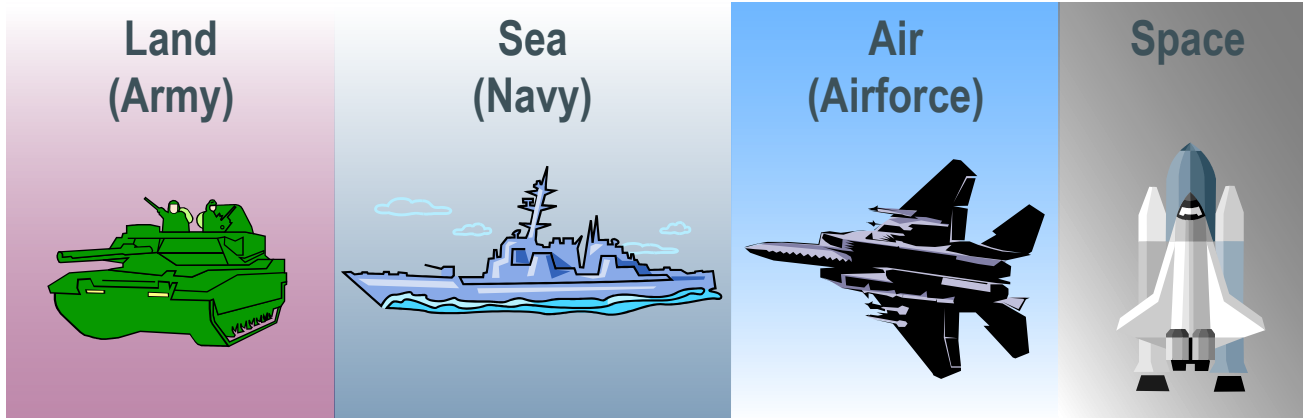
Applicable Standards:

- | CISPR 11
- | IEC 60601-1-2 Ed. 4.0
- | IEC 61000-x-x



A&D Standard Applicability

- ▶ The standard is applicable for subsystems and equipment of:



EMC Standards for the A&D Industry

- ▶ MIL-STD-461 describes requirements for subsystems
- ▶ MIL-STD-464 describes requirements for systems
- ▶ DO-160 Environmental Conditions and Test Procedures for Airborne Equipment



A&D Standard Classification

- ▶ The standard describes in detail the tests which have to be performed on any kind of electronic, electrical or electromechanical equipment used in the military fields.

– The tests are grouped into:

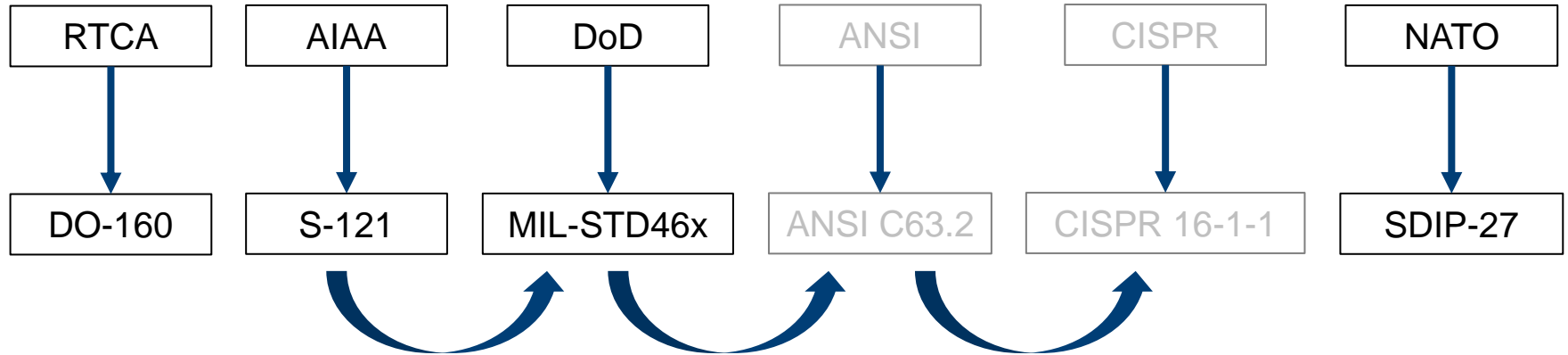
- Emission measurements
- Susceptibility measurements
- Radiated measurements
- Conducted measurements

	Emission	Susceptibility
Radiated	RE1xx	RS1xx
Conducted	CE1xx	CS1xx

History of EMC MIL-STD-461 / 462 / 463

1966			463
1967	461	462	
1968	461A	462 Notice 1	
1969	461A Notice 1 / 2		
1970	461A Notice 3	462 Notice 2	
1971	461A Notice 4	462 Notice 3	
1972			463 Notice 1
1973	461A Notice 5 / 6		
1977			463 A
1980	461B	462 Notice 4	
1986	461C	462 Notice 5	
1987	461C Notice 1 / 2	462 Notice 6	
1993	461D	462D	
1995		462D Notice 1 / 2	
1996		462D Notice 3	
1999	461E		
2007	461F		
2015	461G		

Common EMC Standards in A&D



MIL-STD 461G

MIL-STD-461 Revision G on requirements for the control of EMI Characteristic of Subsystems and Equipment

TABLE II. Bandwidth and measurement time.

Frequency Range	6 dB Resolution Bandwidth	Dwell Time		Minimum Measurement Time Analog-Tuned Measurement Receiver ^{1/}
		Stepped-Tuned Receiver ^{1/} (Seconds)	FFT Receiver ^{2/} (Seconds/ Measurement Bandwidth)	
30 Hz - 1 kHz	10 Hz	0.15	1	0.015 sec/Hz
1 kHz - 10 kHz	100 Hz	0.015	1	0.15 sec/kHz
10 kHz - 150 kHz	1 kHz	0.015	1	0.015 sec/kHz
150 kHz - 10 MHz	10 kHz	0.015	1	1.5 sec/MHz
10 MHz - 30 MHz	10 kHz	0.015	0.15	1.5 sec/MHz
30 MHz - 1 GHz	100 kHz	0.015	0.15	0.15 sec/MHz
Above 1 GHz	1 MHz	0.015	0.015	15 sec/GHz

^{1/} **Alternative scanning technique.** Multiple faster sweeps with the use of a maximum hold function may be used if the total scanning time is equal to or greater than the Minimum Measurement Time defined above.

^{2/} **FFT Receivers.** FFT measurement techniques may be used provided that FFT operation is in accordance with ANSI C63.2. The user interface of the measurement receiver must allow for the direct input of the parameters in Table II for both FFT Time Domain and Frequency Stepped modes of measurement in the same manner, without the necessity or opportunity to control FFT functions directly.

EMC Standards Overview

► Different electronic equipment require compliance to different standards

Commercial Equipment:

- | ISM Equipment
- | Consumer Electronics Equipment
- | IT / Household Equipment
- | Lighting Equipment

Applicable Standards:

- | CISPR 11 to 35
- | IEC/EN61000-X-X series
- | Product Specific Standards

A&D Equipment:

- | Aircraft Equipment
- | Ship & Submarine Equipment
- | Land Based Equipment

Applicable Standards:

- | MIL-STD 461
- | MIL-STD 464
- | RTCA DO 160

Automotive Equipment:

- | Control Equipment
- | Infotainment Equipment
- | Communication Equipment

Applicable Standards:

- | CISPR 12, 25
- | ISO11451, ISO11452
- | Country specific standards
- | OEM Specific Standards

Medical Equipment:

- | Medical devices
- | Diagnostic machines
- | Hearing aids

Applicable Standards:

- | CISPR 11
- | IEC 60601-1-2 Ed. 4.0
- | IEC 61000-x-x

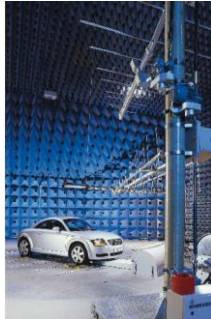


EMC Standards for Automotive

- Internal EMC =
 - Interference between subparts (ESA) inside of a car



- Examples:
 - ABS / ASR / ESB - System
 - Bus System (CAN)
 - Navigation System (GPS)
 - Motors (i. e. windscreen wiper)
 - Microprocessors
 - CD-Player, Radio
 - AC-Ripple
 - Load Dump



- External EMC =
 - Interference of car / car components from the environment

- Examples:
 - High Voltage AC-Lines
 - Lightning
 - Radio (Police, Taxi)
 - Mobile Phone used inside of a car
 - Broadcast transmitter
 - Electrostatic Discharge (ESD)



EMC Standards for Automotive (cont.)

EMC Standards for Vehicles and ESA (Electronic Sub Assemblies)

Car Manufacturer	Global	USA	Europe	China	Japan
MB, TL, GMW, B21, etc.	ISO, CISPR	SAE	2004/104/ EEC	GB...	JASO

EMC Standards for Automotive (cont.)

Manufacturer	International	Europe	USA	Asia
GM 3097 Rev. 3 ESA concerns - EMC	CISPR 12 Vehicle concerns - EMI	2004/104/EEC Vehicle and ESA Concerns EMI + EMS	SAE J551 Vehicle Concerns EMI + EMS	China Vehicle and ESA Concerns - EMI
VW: TL ... ESA concerns - EMC	ISO 11451 Vehicle concerns - EMS			
PSA: B21 7090 Vehicle and ESA concerns - EMC	ISO 10605 Vehicle and ESA concerns - ESD		SAE J1113 ESA Concerns EMI + EMS	Japan Vehicle and ESA Concerns EMI + EMS
FIAT: 9.90110 Vehicle and ESA concerns - EMC	ISO 11452 ESA concerns - EMS			
.	CISPR 25 ESA concerns - EMI			.
.				.
.				.
BMW GS95002 Vehicle and ESA concerns - EMC	ISO 7637 ESA Conducted Pulses			

EMC Standards Overview

► Different electronic equipment require compliance to different standards

Commercial Equipment:

- | ISM Equipment
- | Consumer Electronics Equipment
- | IT / Household Equipment
- | Lighting Equipment

Applicable Standards:

- | CISPR 11 to 35
- | IEC/EN61000-X-X series
- | Product Specific Standards

A&D Equipment:

- | Aircraft Equipment
- | Ship & Submarine Equipment
- | Land Based Equipment

Applicable Standards:

- | MIL-STD 461
- | MIL-STD 464
- | RTCA DO 160

Automotive Equipment:

- | Control Equipment
- | Infotainment Equipment
- | Communication Equipment

Applicable Standards:

- | CISPR 12, 25
- | ISO11451, ISO11452
- | Country specific standards
- | OEM Specific Standards

Medical Equipment:

- | Medical devices
- | Diagnostic machines
- | Hearing aids

Applicable Standards:

- | CISPR 11
- | IEC 60601-1-2 Ed. 4.0
- | IEC 61000-x-x



EMC Standards for Medical

Medical Device Directive - IEC 60601-1-2 Edition 4.0

Phenomenon	Current Ed3 Requirement	Environment				Comment
		Hospital / Large Clinic	Small Clinic	Home	Portable / Transport	
Conducted Emissions	CISPR 11 Class A Class B for Domestic	CISPR 11 Class A	CISPR 11 Class B	CISPR 11 Class B	CISPR 11 Class B ISO 7137 aircraft DO 160	CISPR 11 Class A/B still apply. No major change except Transport
Radiated Emissions	CISPR 11 Class A Class B for Domestic	CISPR 11 Class A	CISPR 11 Class B	CISPR 11 Class B	CISPR 11 Class B ISO 7137 aircraft DO 160	CISPR 11 Class A/B still apply. No major change except Transport

- Harmonic and Flicker requirements
- Defined by 61000-3-2 and 61000-3-3 standards

EMC Standards for Medical

- Typically – **80% to 90% of all failures** are due to:
- Radiated / Conducted Emission Testing (CISPR11)
 - Radiated Immunity Testing (IEC 61000-4-3)
 - Electrostatic Discharge Testing (IEC 61000-4-2)

Test Standard	Edition 3 Levels	Edition 4 Levels
CISPR 11 Radiated Emissions	CISPR 11 Class A Class B for Domestic	CISPR 11 Class A Class B - Clinics
CISPR 11 Conducted Emissions	CISPR 11 Class A Class B for Domestic	CISPR 11 Class A Class B for Clinics
IEC 61000-4-2 ESD	8 kV Air Discharge 6 kV Contact Discharge	15 kV Air Discharge 8 kV Contact Discharge
IEC 61000-4-3 Radiated Immunity	3 V/m / 80 - 2,500 MHz	30 V/m / 80 MHz to 6 GHz
IEC 61000-4-4 Electrical Fast Transients / Burst	2 kV AC Lines / 1 kV I/O Lines	2 kV AC Lines / 1 kV I/O Lines
IEC 61000-4-5 Power Surge Immunity	2 kV AC Lines	2 kV AC Lines
IEC 61000-4-6 Conducted RF Immunity	3 V RMS	3 V RMS & 10 V RMS ISM Frequencies
IEC 61000-4-8 Magnetic Fields	3 A/m 50/60Hz	30 A/m 50/60 Hz
IEC 61000-4-11 Voltage Dips / Interruptions	>5 % Un; 0.5 & 300 Cycles / 40 % / 70%	0 % Un; 1 Cycle / 300 Cycles / 70 %
IEC 61000-3-2 Current Harmonics	No Change, tested at 50 or 60 Hz	No Change, tested at 50 or 60 Hz
IEC 61000-3-3 Flicker and Fluctuations	No Change, tested at 50 Hz	No Change, tested at 50 Hz

Summary

- ▶ Commercial, aerospace & defense, automotive, and medical industries have plenty of applicable standards
- ▶ EMC standards define the rules for testing, including methodology, equipment, and environment
- ▶ EMC standards are typically divided into two major categories: EMI (emissions) and EMS (susceptibility)
- ▶ Several standardization bodies exist at both the global and regional levels



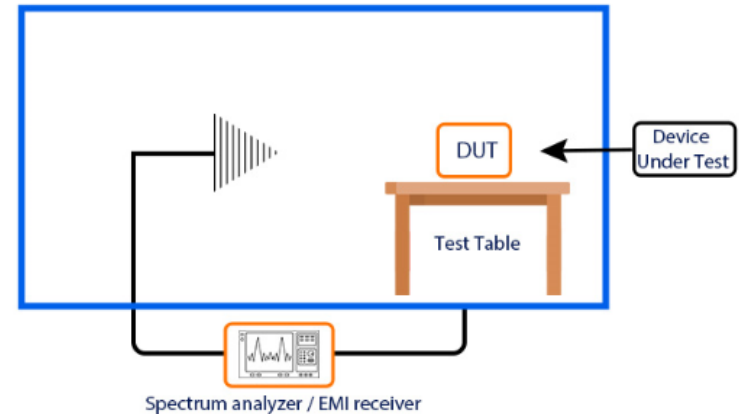
TEST TYPES

EMC Testing Methods

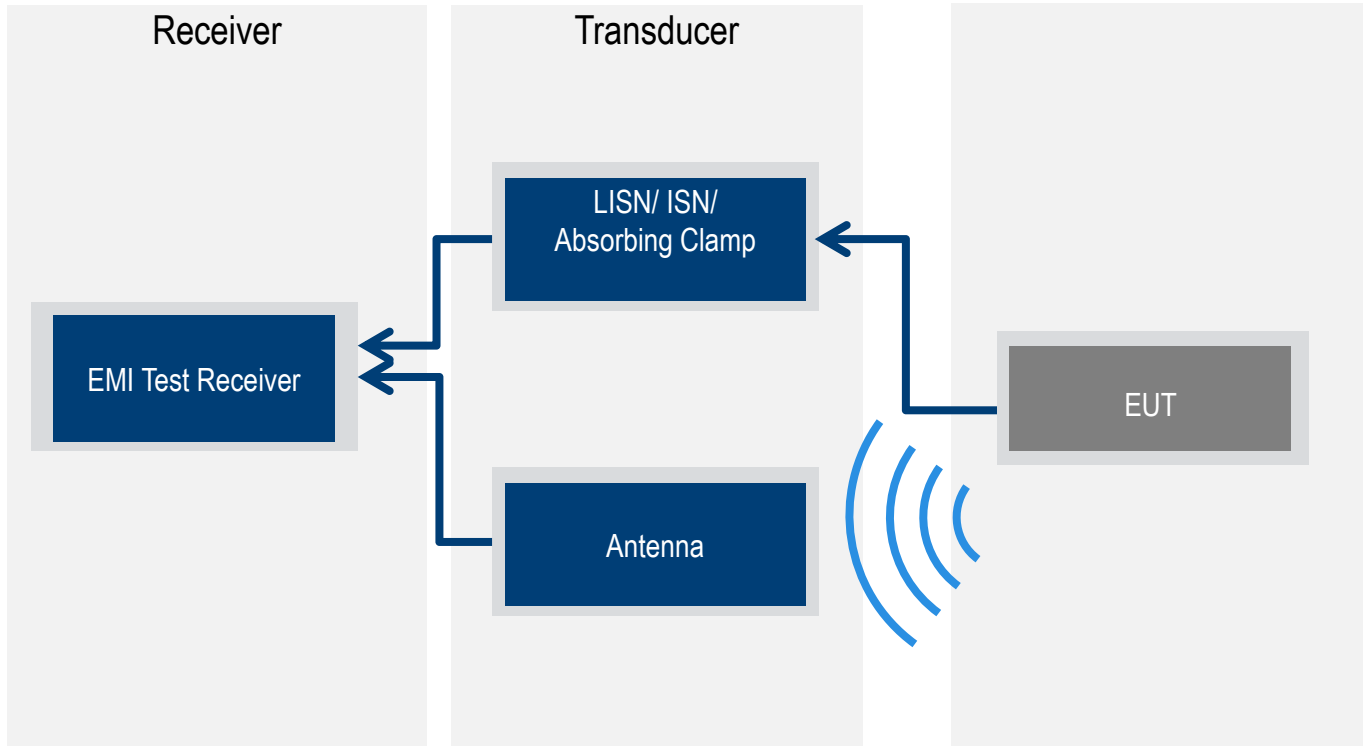
	Radiated	Conducted
Emissions	RE	CE
Immunity / Susceptibility	RI / RS	CI / CS

Emissions Testing

- ▶ **Radiated Emissions (RE)**: Test is done to detect and quantify any unintentional electromagnetic radiation from the test article. This aids in the early detection of possible electromagnetic interference (EMI) sources during the development phase.
- ▶ **Conducted Emissions (CE)**: In this test, emissions through power and signal cables are assessed. It assists in figuring out whether the cables and connections from the DUT are causing any undesired emissions.
- ▶ **Harmonics and Flicker Analysis**: As part of the emission testing in pre-compliance, the product's electrical current and voltage are assessed for harmonic distortion and flicker. Early detection and resolution of harmonic and flicker problems might help avoid formal compliance testing.

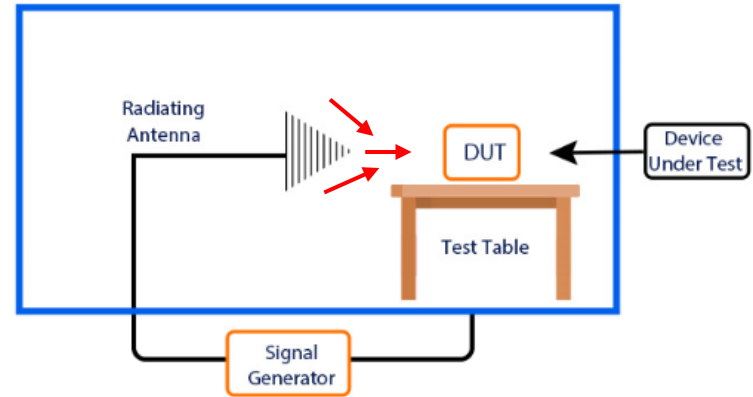


EMI / Emissions Test System (Typical)

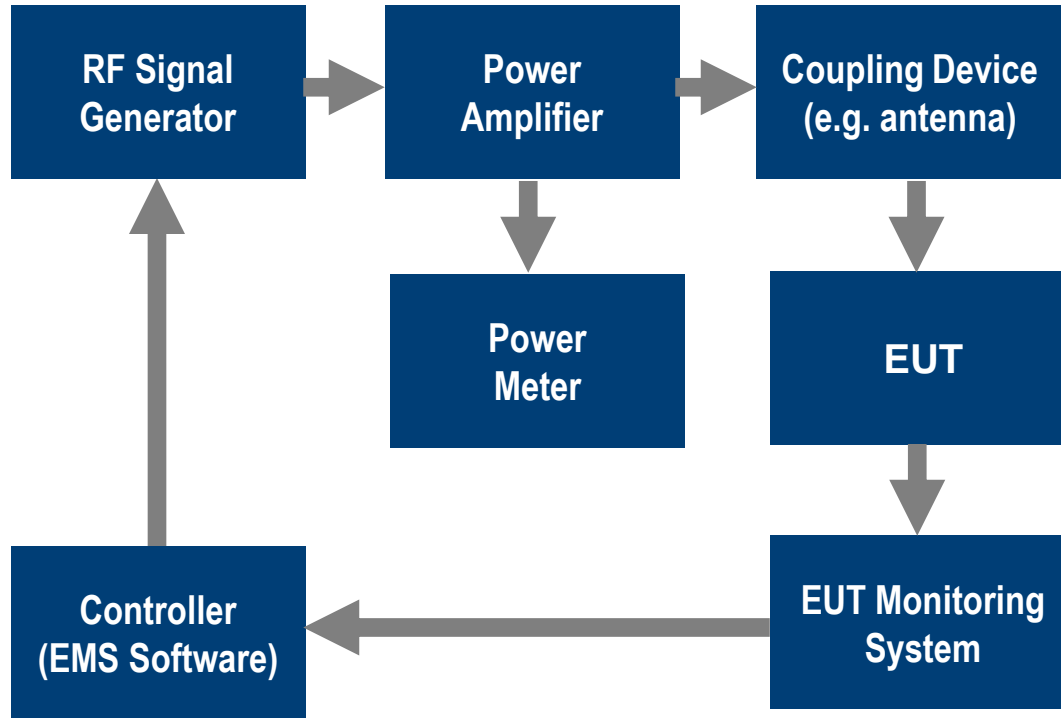


Immunity Testing

- ▶ **Radiated Immunity (RI)**: Test is done to evaluate the degree to which the test article can tolerate exposure to electromagnetic fields that are radiated, such as radiofrequency interference (RFI) which might reveal the weaknesses to external EMI of the test article.
- ▶ **Conducted Immunity (CI)**: In this test, immunity through power and signal cables are assessed. Evaluation of power and signal lines immunity can reveal vulnerabilities in the test article's reaction to conducted disturbances, such as voltage dips and electrical fast transients (EFT).
- ▶ **Transient Immunity (Voltage and Current Spikes)**: Voltage and current transients, such as electrostatic discharges (ESD) and EFT are used in this test to determine the resiliency of the test article to these frequent disruptions.



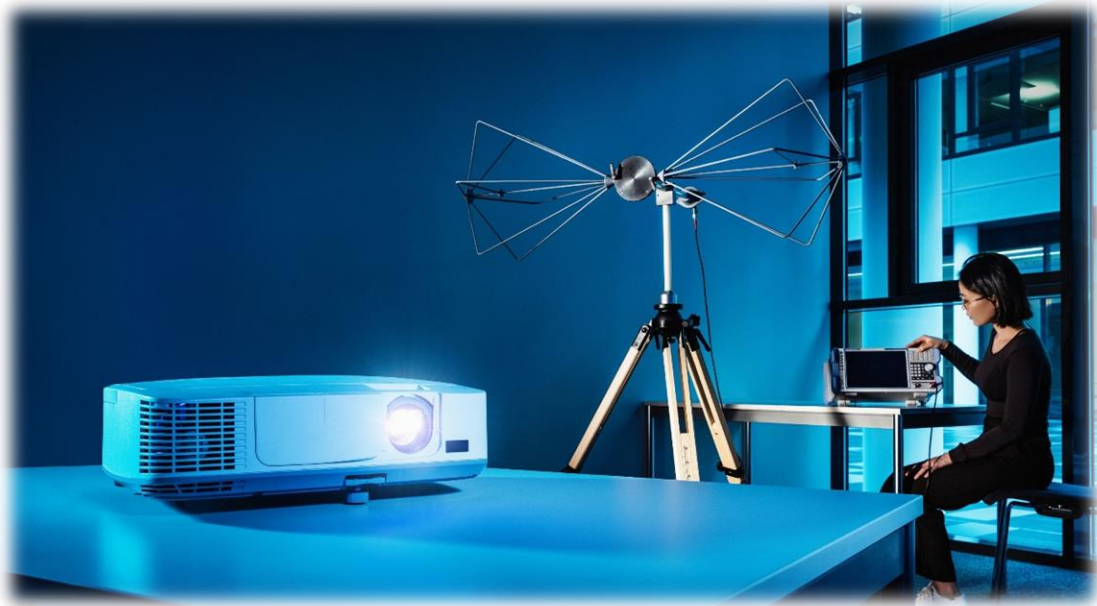
EMS / Immunity Test System (Typical)



The Electromagnetic Spectrum

- ▶ Most EMC issues occur in the range 9kHz – 6GHz.
- ▶ Conducted emissions tend to occur below 30MHz.
- ▶ Radiated emissions tend to occur above 30MHz.

Band	Freq Range	Wavelength
HF	3-30MHz	100m – 10m
VHF	30-300MHz	10m – 1m
UHF	300-1000MHz	1m – 30cm
L	1-2GHz	30cm – 15cm
S	2-4GHz	15cm – 7.5cm
C	4-8GHz	7.5cm – 3.75cm
X	8-12GHz	3.75cm – 2.5cm
Ku	12-18GHz	2.5cm – 1.67cm
K	18-27GHz	1.67cm – 1.11cm
Ka	27-40GHz	1.11cm – 0.75cm



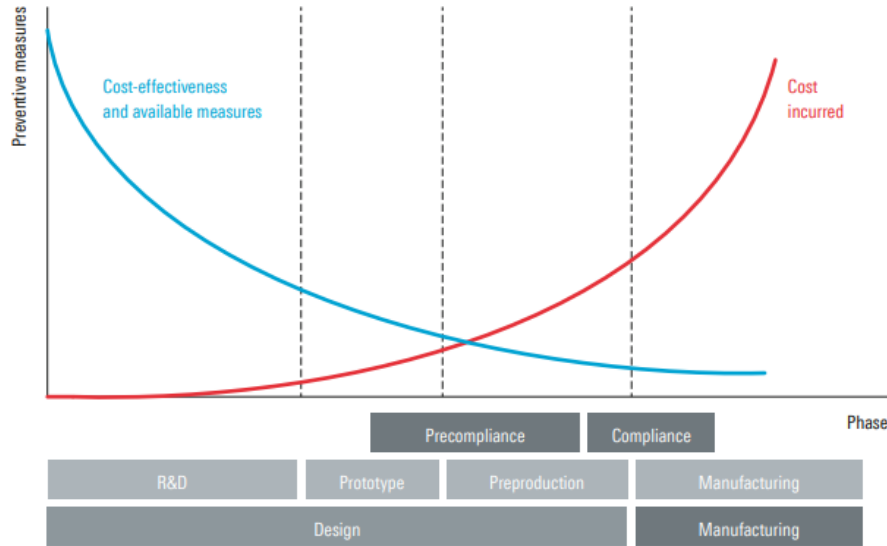
PRE-COMPLIANCE TESTING

What is EMC Pre-Compliance?

- ▶ EMC Pre-compliance testing can be defined as the preliminary evaluation of an electronic device's electromagnetic emissions and susceptibility to interference.
- ▶ This testing (or a procedure) is conducted in a controlled laboratory environment using specialized testing equipment to identify potential problems early in your design process, before full-scale testing takes place
 - This gives you an incremental, stage-by-stage portrait of your product and its potential EMC-related design flaws, helping you avoid inconvenient product redesigns that can result when testing is put off until the final phase of the design plan.
 - EMC testing outcomes are usually specific to a product's design, meaning that EMC technicalities particular to a design plan can stop a product from passing.

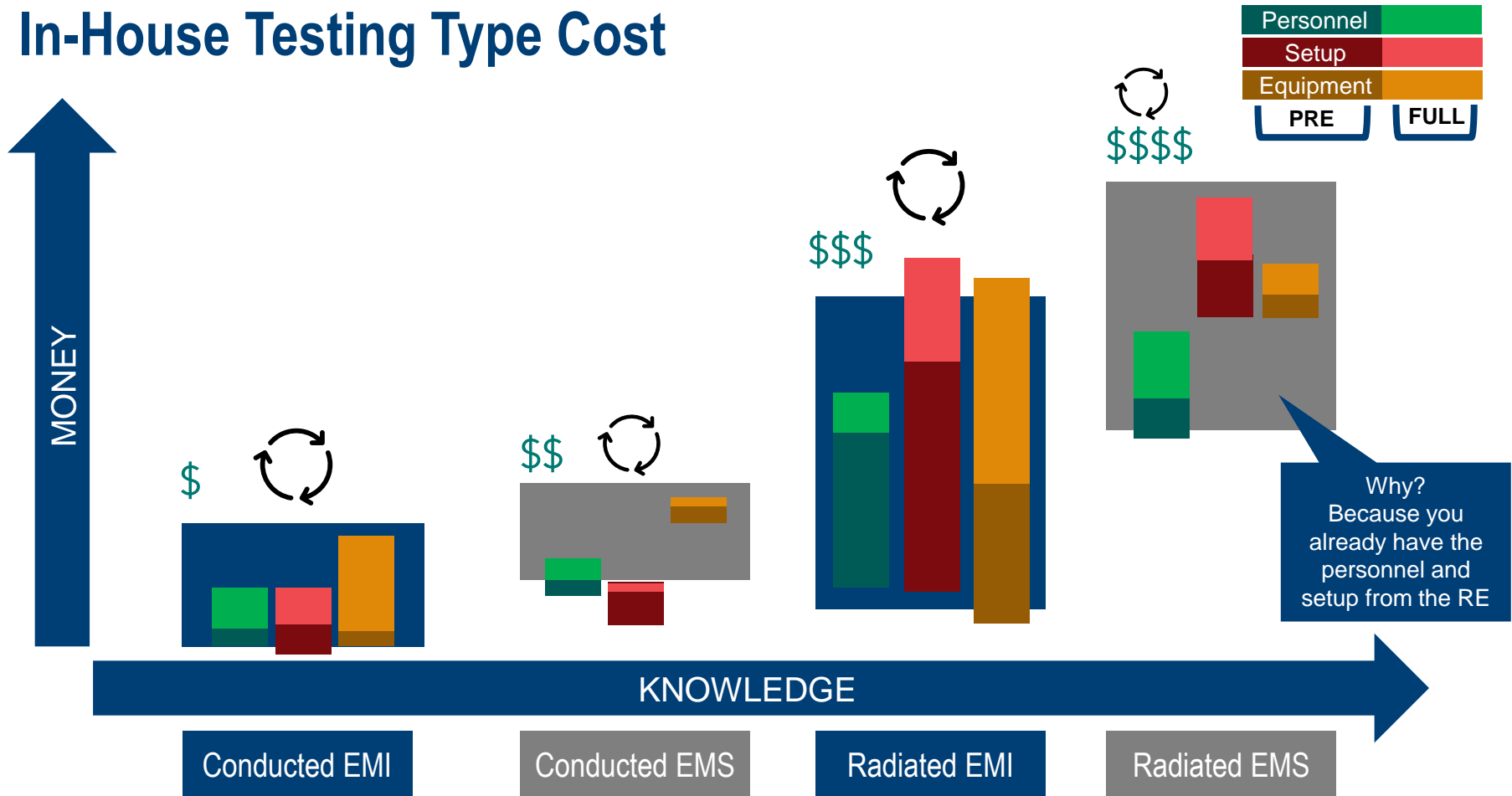
Pre-compliance testing can help increase success rates in EMC certification tests, avoid costly errors in design, and accelerate time to market

When to Perform Pre-Compliance ?

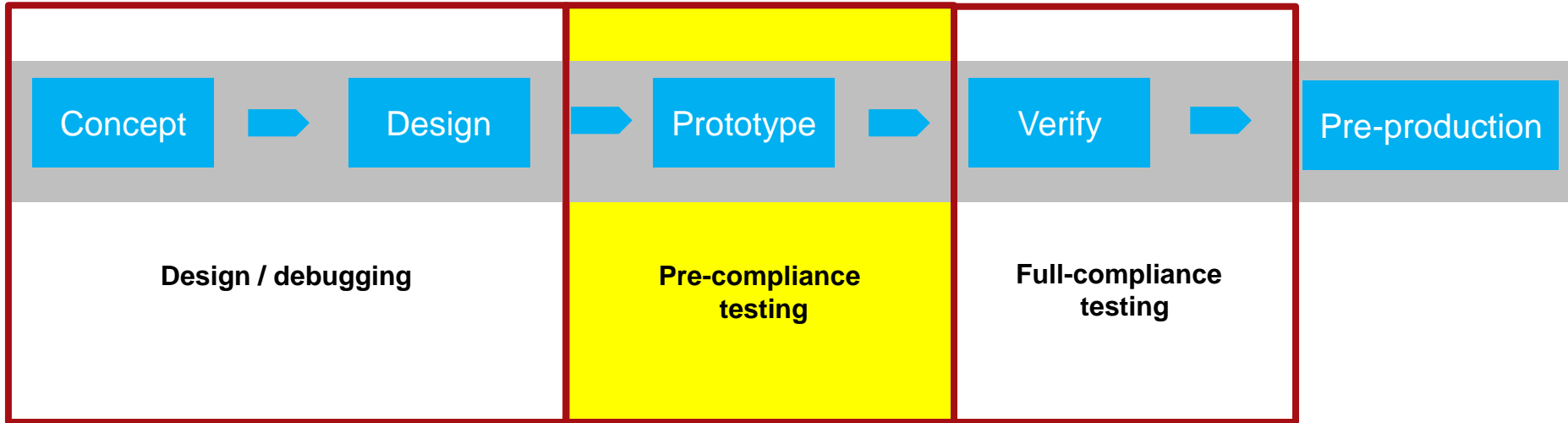


- ▶ Pre-compliance and debugging tests should already be performed during prototyping and preproduction stages of product development to ensure that EMC standards are adhered to.
- ▶ EMC testing is a critical part of any product development journey, since electromagnetic interference can come from many sources, with different characteristics and mechanisms.
- ▶ Electromagnetic interference (EMI) is always an unwanted occurrence, and the overall aim is to eliminate or reduce it below certain limits.

In-House Testing Type Cost



What is a customer's typical workflow?



Customer concerns:

- How can I make sure I pass compliance the first time?
- How long will it take me to do all these tests?
- Is it worth buying my own equipment, or using a test lab to do it for me?

Mapping solutions to the product design workflow

Concept

Design

Prototype

Verify

Pre-production

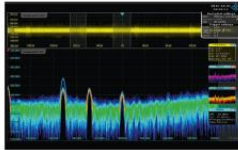
Design for test – first level debugging

Pre-compliance

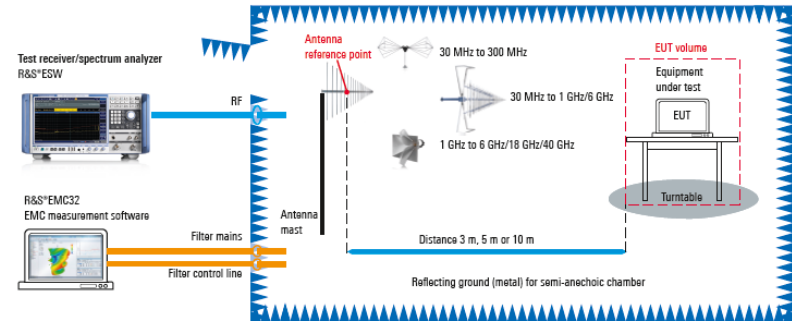
Compliance



Spectrum Analyzer
 | Near field
 | Weighted detector
 | Interference analysis
 | Excellent Sensitivity



Oscilloscopes
 | Near field
 | Time/freq correlation
 | Reference masking
 | Serial/parallel/protocol test



R&S®ESL and FSL



R&S®ESRP and FSV3000

EMI Test Receiver
 | Conducted and radiated measurement
 | Precompliance and compliance acc. to CISPR/EN/MIL/etc. standard
 | High measurement speed
 | Disturbance measurement



R&S®ESW



R&S®ESR

Typical R&S solutions for the customer workflow

Concept



Design

Design / Debugging



Oscilloscopes



Spectrum Analyzers

Prototype



Pre-compliance



EMI Test Receivers



Spectrum Analyzers

Verify



Full-compliance



EMI Test Receivers

Pre-production

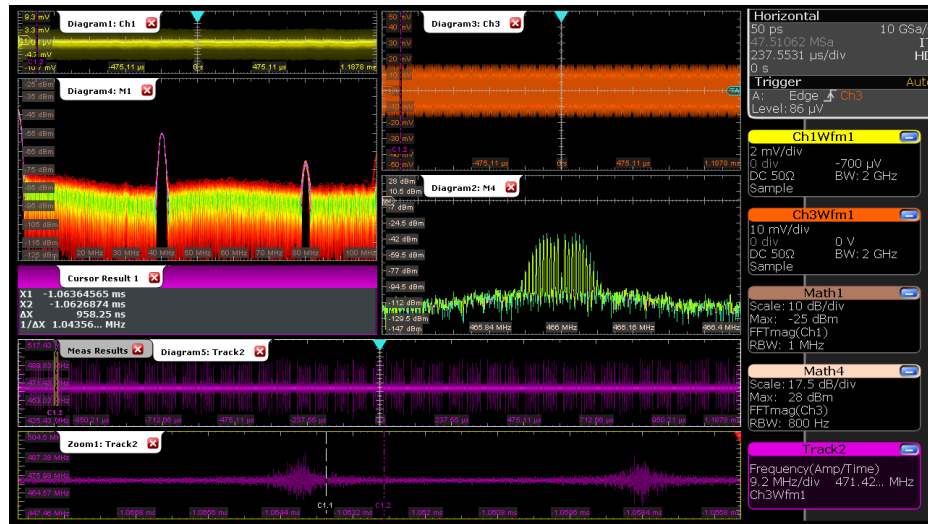
Oscilloscopes for Pre-Compliance

► Pros

- Multi-domain analysis
- Wide analysis bandwidth
- **USP:** Frequency Zone Trigger
- **USP:** Spectrum Analyzer-Like UX
- **USP:** Overlap and Gating

► Cons

- No preselection
- No time domain scan
- No limit lines for EMC standards
- Limited frequency range



Typical R&S solutions for the customer workflow

Concept



Design

Design / Debugging



Oscilloscopes



Spectrum Analyzers

Prototype



Pre-compliance



EMI Test Receivers



Spectrum Analyzers

Verify



Full-compliance



EMI Test Receivers

Pre-production

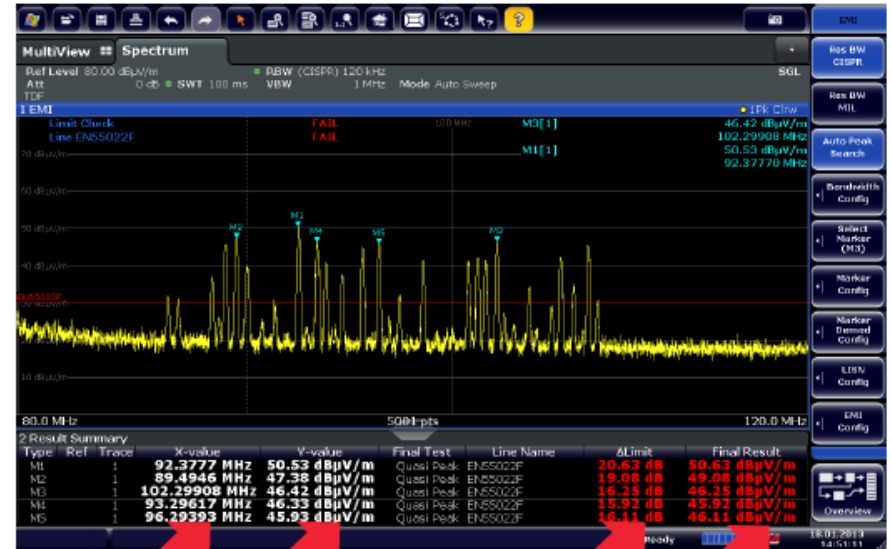
Spectrum Analyzers for Pre-Compliance

► Pros

- K54 option gets you some EMC features
- Best in class RF performance (DANL)
- Spectrogram available for troubleshooting
- Other Wireless application support

► Cons

- No preselection
- No time domain scan
- Advanced EMI SW (ELEKTRA) not integrated in unit



Typical R&S solutions for the customer workflow

Concept



Design

Design / Debugging



Oscilloscopes



Spectrum Analyzers

Prototype



Pre-compliance



EMI Test Receivers



Spectrum Analyzers

Verify



Full-compliance



EMI Test Receivers

Pre-production



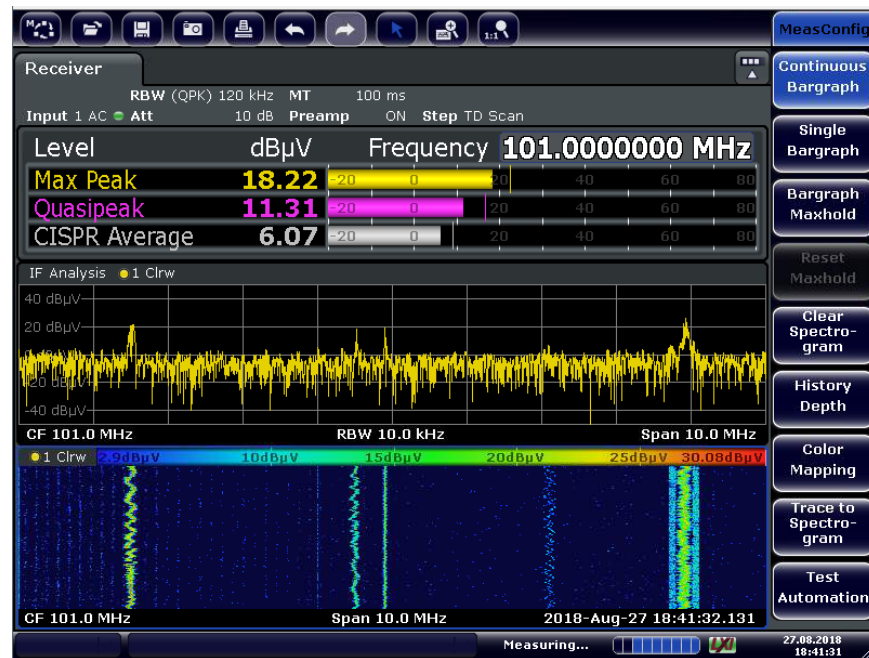
Receivers for Pre-Compliance

► Pros

- Designed to look for unknown signals
- Pre-selection is in the EMC standards
- Time domain scan speeds up QP scans
- Ease of use for standards testing

► Cons

- Generally most expensive option



Pre-Compliance Solutions

Feature	EMI Receiver	Spectrum Analyzer	Oscilloscope
General purpose RF	-	✓	✓
Wireless standards WLAN, IOT, Cellular	-	✓	✓
Serial data bus decode	-	-	✓
EMI detectors / bandwidths (incl. QP)	✓	✓	-
EMI Meas. Dynamic Range & Sensitivity	Very high / Very high	High / Very high	Medium
Log-scale & limit lines	✓	✓	(✓)
Scan Types	All (Sweep, step, time-domain, zero-span)	Some (Sweep, zero-span)	No scan
Time/frequency correlation possible	✓	✓	✓
Gapless recording	Very long	Long	Medium
Auto ranging	✓	-	-

EMC Pre-Compliance accessories

Conducted Emissions:

Line Impedance Stabilization Network: HM6050



Radiated Emissions: Directional antenna

HL223: 200 MHz to 1.3 GHz



Radiated Emissions - Wooden Tripod HZ-1,

HK116E: Biconical Antenna 20 to 300 MHz



Troubleshooting:

Near Field Probes HZ-14: 9 kHz to 30 MHz



Troubleshooting: E & H Field Near Field

Probes

HZ-15: 30 MHz to 3 GHz



Troubleshooting:

Preamplifier for Probing: HZ-16

3 GHz, 20 dB gain



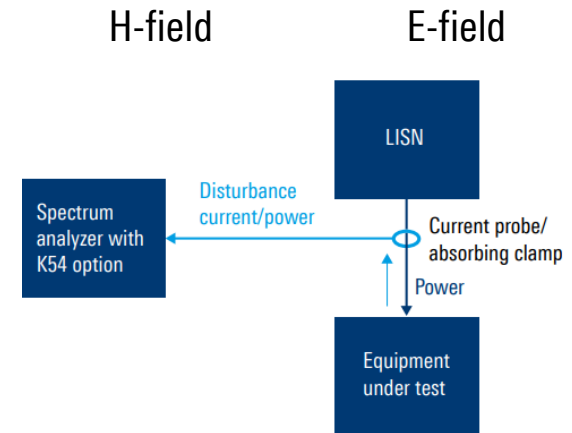
Line Impedance Stabilization Network (LISN)

- ▶ LISN is a device used in EMC testing to standardize the impedance of power and signal lines to ensure that electronic devices are tested under consistent conditions, helping assess their electromagnetic emissions and susceptibility.
- ▶ The main functionality of the LISN is to
 - Provide a stable impedance on AC mains
 - Block RF signals on AC mains from entering the equipment under test
- ▶ Used in Conducted Emissions Testing



Probes

- ▶ Near-field probes are used as diagnostic tools for locating EMC problems, e.g. on circuit boards, integrated circuits, cables and shielding – ideal for emission measurements from 30 MHz to 3 GHz.
- ▶ Each probe has different pros and cons, so it is beneficial to have a set of probes at your disposal. Probing always starts with bigger probes to locate the general problematic area more easily, and then uses smaller ones to locate the exact source of the noise.
- ▶ Fast changes of current (high di/dt) and fast changes of voltage (high dv/dt) cause emissions.
- ▶ Areas of high di/dt can be localized by means of an H-field probe, typically a probe with loop shape.
- ▶ E-field probes help to detect areas of high dv/dt . Once the area with high di/dt or high dv/dt has been found, a smaller probe size is used to identify the point of emission with higher resolution.



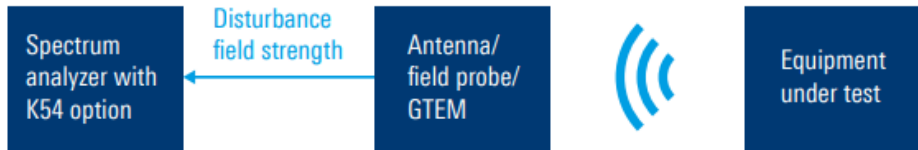
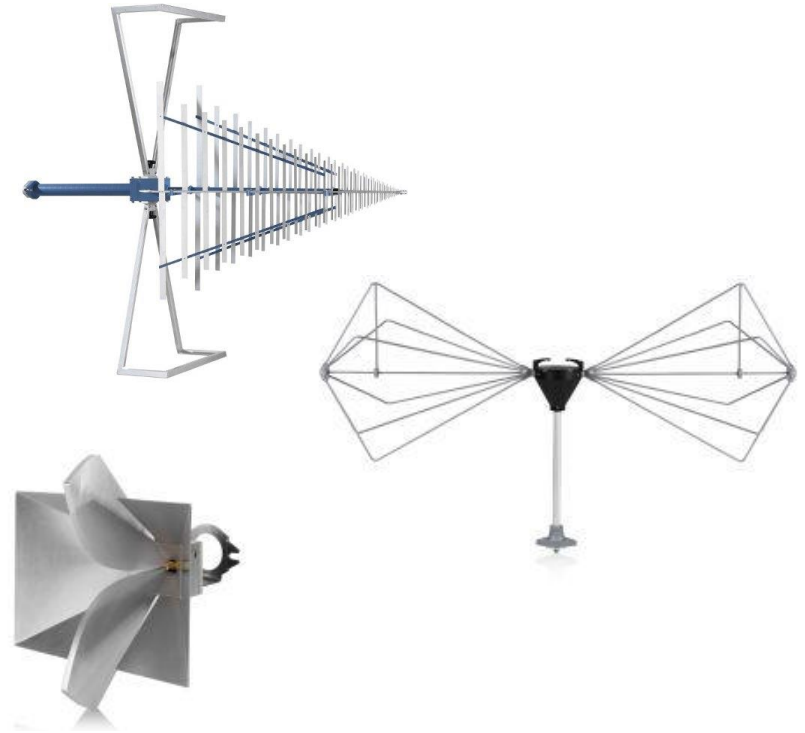
Current Probes

- ▶ Used for measuring emissions from cables
 - Cables often act as the antenna for the emissions because they are electrically long
- ▶ Typically don't see many ambient emissions
- ▶ Simple and low cost



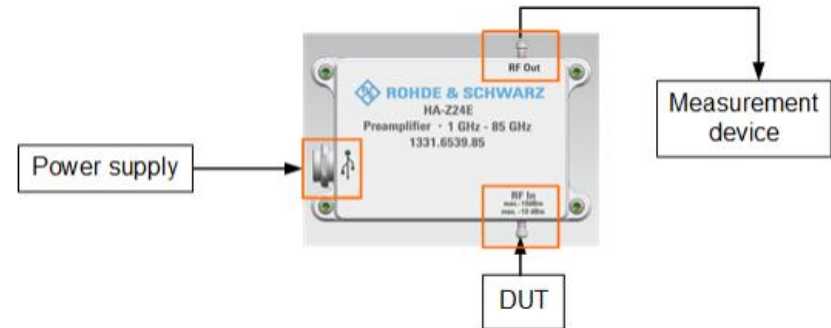
Antennas

- ▶ Antennas are specialized antennas designed for radiated emissions and immunity testing. They transmit and receive electromagnetic signals during EMC assessments, helping in the measurement of the electromagnetic compatibility of electronic devices.
- ▶ The main functionality of the Antennas is to
 - Act as Rx/Tx (based on emissions or immunity) over a wide range of frequencies.
- ▶ Used in Conducted and Radiated Testing



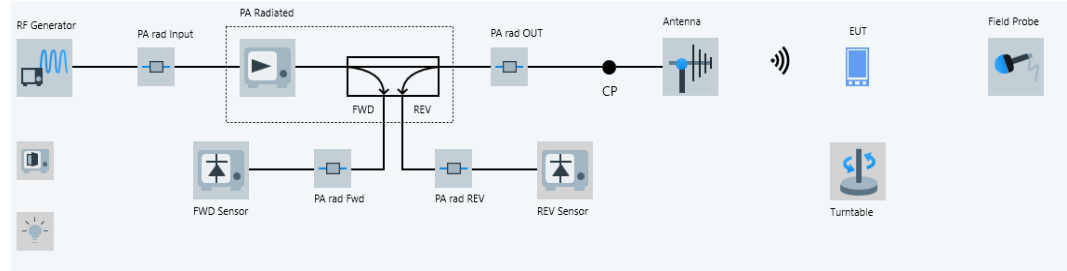
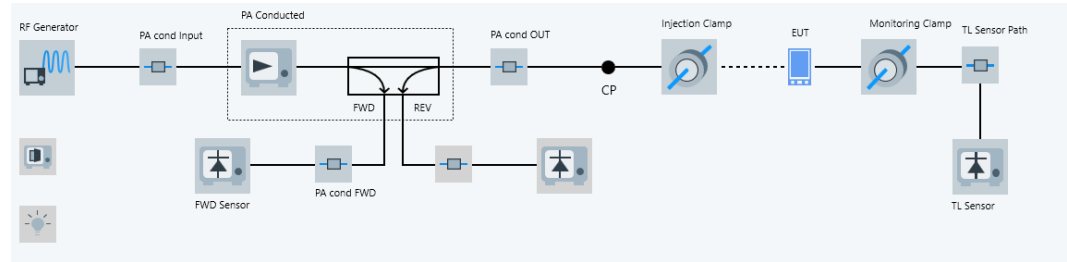
Pre-Amplifier

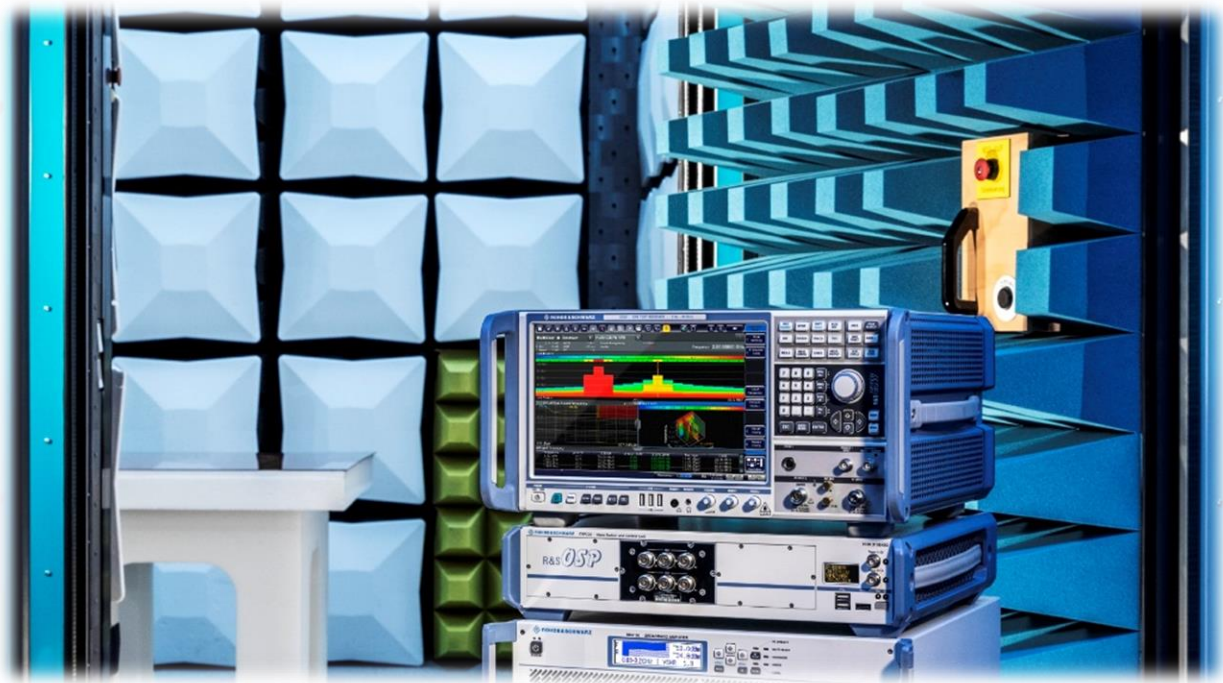
- ▶ Pre-amplifier is inserted between the near-field probe (or antenna) and the spectrum analyzer to amplify the signals from the test article making it easier to measure very weak high-frequency fields of up to 3 GHz.
- ▶ The main functionality of the pre-amp
 - is to measure signals from devices under test with low output power, using measurement devices which feature a low sensitivity



Need for Automation

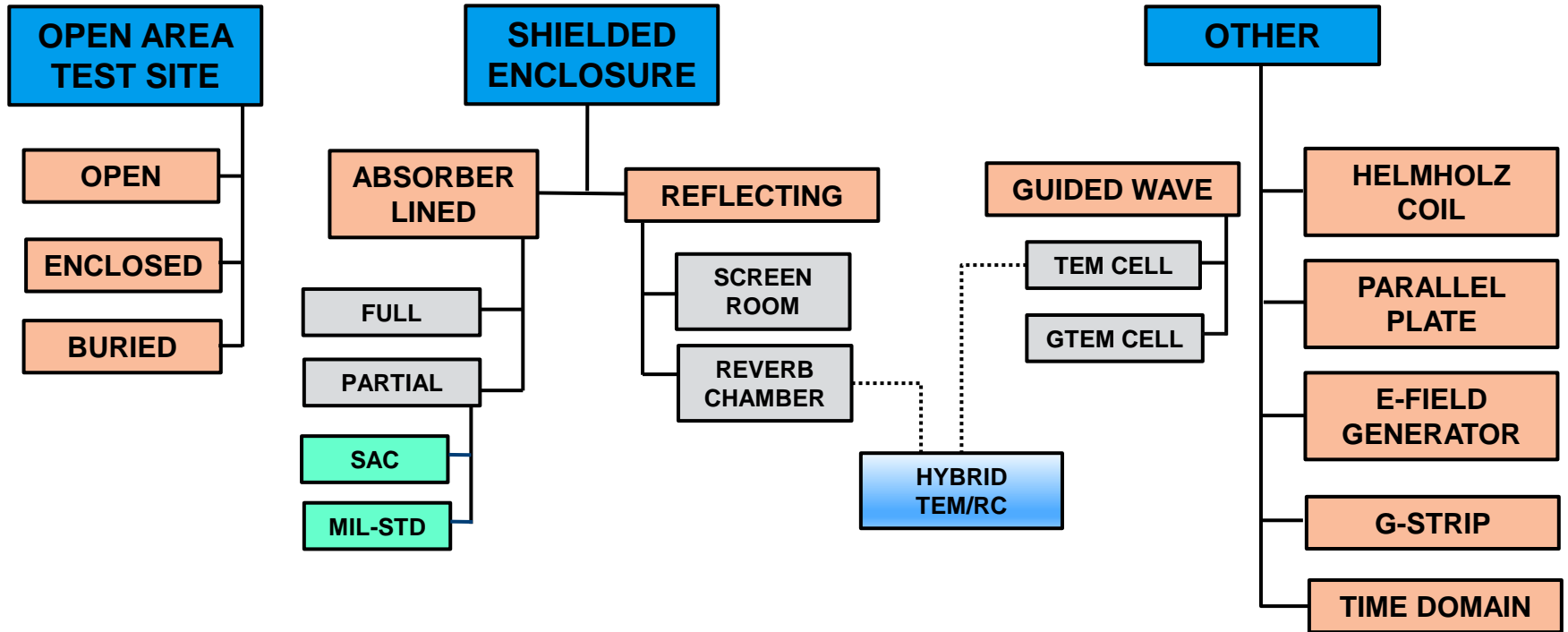
- ▶ Automated systems helps to analyze, manage, and optimize electromagnetic emissions and immunity testing and engineers in modelling, simulating, and assessing the impact of electromagnetic interference (EMI) on equipment and systems.
- ▶ Higher speed and better repeatability than manual operation
- ▶ Compensates for antennas, cables, etc.
- ▶ R&S product offering
 - EMI test software “Elektra”
 - Preconfigured measurement settings for relevant EMC standards
 - Automation
 - Reporting





FULL COMPLIANCE - CHAMBERS

Testing Facilities



ANECHOIC CHAMBERS

COMPANY RESTRICTED

Anechoic Chambers

- ▶ An anechoic chamber (AC) is a shielded enclosure with all interior surfaces lined with EM absorbing material. An ideal AC would have no reflected energy.
- ▶ Also called an absorber lined chamber (ALC) or fully absorber lined chamber (FALC).
- ▶ Test environment
 - Propagating spherical wave
 - Linearly polarized
 - Ambient isolated



AC - Facility Description

- ▶ Typically, a rectangular shielded enclosure
 - Other shapes possible
 - Single / multiple tapered sections
- ▶ Lined with tapered or pyramidal carbon loaded absorbers
 - Requires ferrite absorbers for low frequencies
- ▶ Absorber performance requires less than 20 dB reflectivity

AC - Facility Description

- ▶ TX / RX antenna to EUT distance from 1 to 10 m
- ▶ For emissions testing
 - Quiet zone defined by received power at fixed RX antenna location for 15 positions and two polarizations of TX antenna
 - Quiet zone minimum generally 2 m diameter and 1 m height
 - “rule-of-thumb” maximum quiet zone ~ one-third smallest chamber dimension
- ▶ For immunity testing
 - Uniformity over 1.5 x 1.5 m plane for two polarizations
- ▶ TX / RX antennas may be offset from centerline
 - To minimize symmetric interference effects
- ▶ To provide “permanent” vertical and horizontal antenna setups to reduce test time

Nature of Electromagnetic Environment (EME) and Working Volume

EME

- ▶ For well designed AC the measured field in an emissions test or test field in an immunity test will be dominated by direct wave.
- ▶ At low frequencies the EUT may be in near field depending on test distance
- ▶ Reflections from non-ideal absorbers can introduce transverse and longitudinal components

Working Volume

- ▶ Generally small working volume to total volume ratio
- ▶ Emissions
 - Quiet zone of 2+ m in diameter and 1+ m in height
- ▶ Immunity
 - Working volume not generally defined
 - Depth of 1.5 x 1.5 m calibration plane not specified

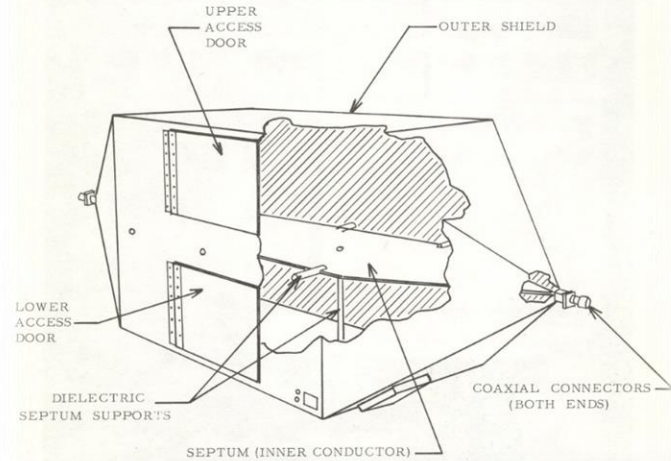
TRANSVERSE ELECTROMAGNETIC CELL (TEM)

TEM Cell

- ▶ A TEM cell is a section of rectangular, coaxial transmission line.
- ▶ Developed by M. Crawford, US National Bureau of Standards (~1973). Often called a Crawford Cell.
- ▶ Test environment
 - Ambient isolated
 - Some concept variations not ambient isolated
 - Linearly polarized
 - Transverse electromagnetic wave

TEM - Facility Description

- ▶ A TEM cell is a rectangular, two conductor transmission line.
- ▶ Symmetric tapered transition sections terminate in coaxial connectors at each end.
- ▶ The walls act as the outer conductor of the coaxial transmission line.
- ▶ The inner conductor is called the septum.
- ▶ Mostly symmetric septum
- ▶ The tapered sections must be long enough to minimize impedance mismatches and undesired reflections.
- ▶ Some manufacturers offer a TEM cell variant without side walls.



TEM - Facility Description

- ▶ Testing can be performed in one or both volumes above and below the septum.
- ▶ Within limits, a septum offset in height can provide a larger working volume as well as testing at a higher field strength in the smaller working volume.
- ▶ A TEM cell does not have either a transmit or reference/monitor antenna. The cell is its own transducer. This permits complex wave simulation without distortion. Further, uncertainties associated with antenna factors, polarization, and directivity effects do not arise.
- ▶ A TEM cell is a reciprocal device.
 - Feed can be input or output
 - Can be switched from immunity to emissions by changing what is attached to feed

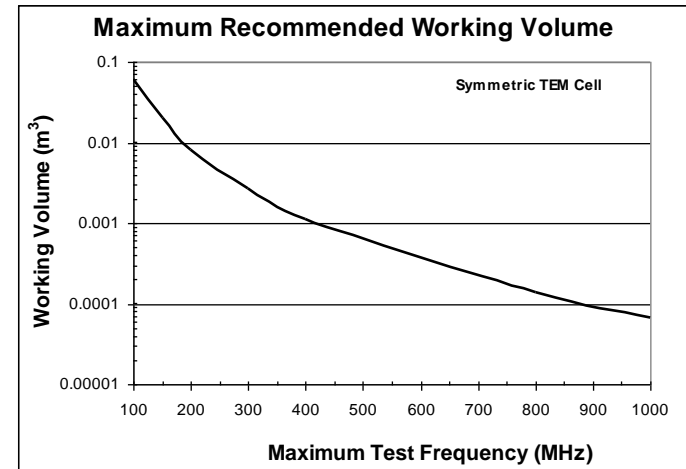
Nature of Electromagnetic Environment (EME) and Working Volume

EME

- ▶ Without an EUT and within its operating frequency range, a TEM cell has a propagating plane wave with variable E field direction and amplitude over a cross-sectional plane.
- ▶ The primary (and desired) field is vertical E-field in working volume.
- ▶ The electric field uniformity is analytically calculable.
- ▶ A TEM cell provides a precision test environment with an uncertainty of ≤ 1 dB possible
- ▶ With an EUT the EME may depart from a plane wave depending on the EUT size and shape, the TEM cell size and the frequency.

Working Volume

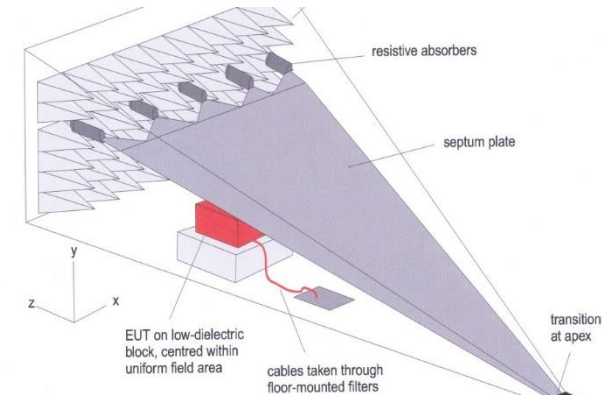
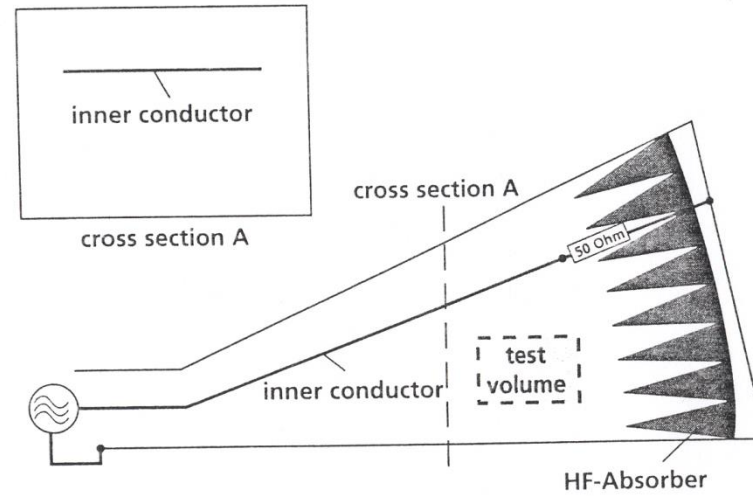
- ▶ Applying the 1/3 “rule” the maximum recommended working volume is shown as a function of the maximum test frequency



GIGAHERTZ TRANSVERSE ELECTROMAGNETIC CELL (GTEM)

GTEM Cell

- ▶ A GTEM, is a rectangular transmission line which is flared along its longitudinal axis.
 - Developed by D. Hansen, ABB (Switzerland) 1984.
- ▶ A GTEM provides a linearly polarized, transverse electromagnetic spherical wave test environment.



GTEM - Facility Description

- ▶ A 50Ω characteristic impedance is maintained throughout the working volume.
- ▶ The septum is terminated in a 50Ω resistance. The propagating field is terminated in a spherical array of RF absorbers.
- ▶ A GTEM cell does not have either a TX or reference/monitor antenna. The cell is its own transducer. This permits complex wave simulation without distortion.
- ▶ GTEM cell is a reciprocal device that can be switched from immunity to emissions by changing what is attached to feed.

Nature of Electromagnetic Environment (EME) and Working Volume

EME

- ▶ Without an EUT and within its operating frequency range, a GTEM provides a propagating spherical wave.
- ▶ With an EUT the EME may depart from a propagating spherical wave depending on the EUT size and shape, and the GTEM size and the frequency. The EUT is in the far field.
- ▶ Testing with a ground plane requirement generally not available. The primary (and desired) field is vertically polarized transverse electromagnetic wave. A variable field strength longitudinal component is also present due to imperfect terminations.

Working Volume

- ▶ Recommended test area is one-third of spectrum height and cell width.
- ▶ Recommended working volume is ~ 1% of total facility volume.
- ▶ Working volume varies with GTEM size.
 - To obtain larger working volume the longitudinal dimension is increased

REVERBERATION CHAMBERS (RC)

Reverberation Chambers

- ▶ A shielded enclosure with a mechanism for mode excitation operated at frequencies where it is multi-moded.
- ▶ First known reference, a US patent 1947
- ▶ Proposed for EMC measurements by H.A. Mendes in 1968

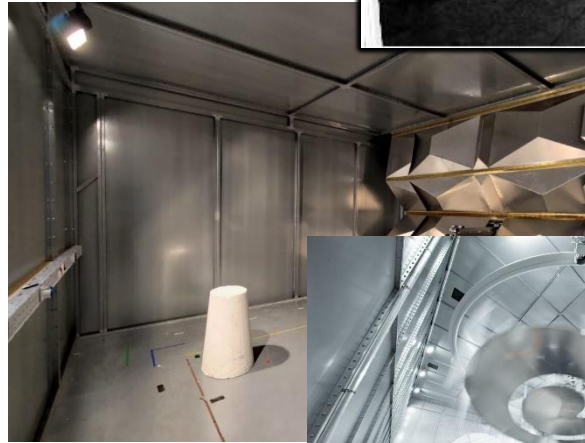
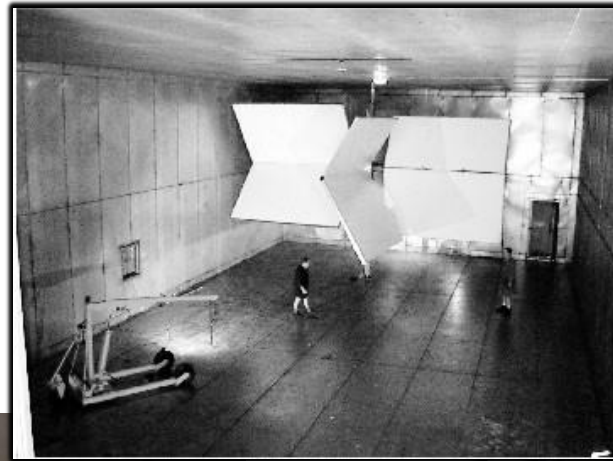


Fig 2.2

RC - Facility Description

- ▶ A SE of any size or shape
 - Range of verified performance
 - 0.58 x 0.81 x 1.0m (0.5m³) to 8 x 14.7 x 20m (2355m³)
 - Demonstrated for wire mesh to welded aluminum SEs
- ▶ No interior absorbers (e.g. wooden test benches, floors, etc.)
 - Any material which gets hot in microwave oven should be avoided
- ▶ Mechanism for exciting modal structure
 - Metal paddle wheel tuner most common
 - Electronic excitation using band limited white Gaussian noise (BLWGN) a potential alternative

RC - Facility Description

- ▶ Tuner design
 - The tuner is used to change boundary conditions or in an alternate (ray tracing) perspective to redistribute energy
 - The tuner should minimize the "unstirred energy"
 - The primary design requirement is that the tuner should be electrically large ($>\lambda/2$ at the LUF)
 - Should be as large as possible
 - Should have a projected area which is a significant fraction of one RC surface
- ▶ Should be shaped and oriented to reflect energy to all RC surfaces
 - Tuner designs range from a single, simple flat plate to multiple, many sided, asymmetric paddles
 - Major design constraint is to have as large an area as possible without degrading EUT location options

RC - Facility Description

- ▶ Tuner location should provide for multiple scattering of cavity fields
 - Experimental data indicate a corner location is effective
- ▶ TX antenna "looking into" the tuner is good setup, however there should not be a single bounce reflection to the EUT or to the RX (monitor) antenna
 - The EUT or RX antenna should not shadow the tuner
- ▶ The tuner should be driven by an external stepper motor with a dielectric shaft or shielded internal motor
 - Should permit small steps
 - Motion should be as smooth as possible
 - Rates should permit rotations from about 1 rps to 1 rpm or greater
 - Tuner motion should be computer controlled

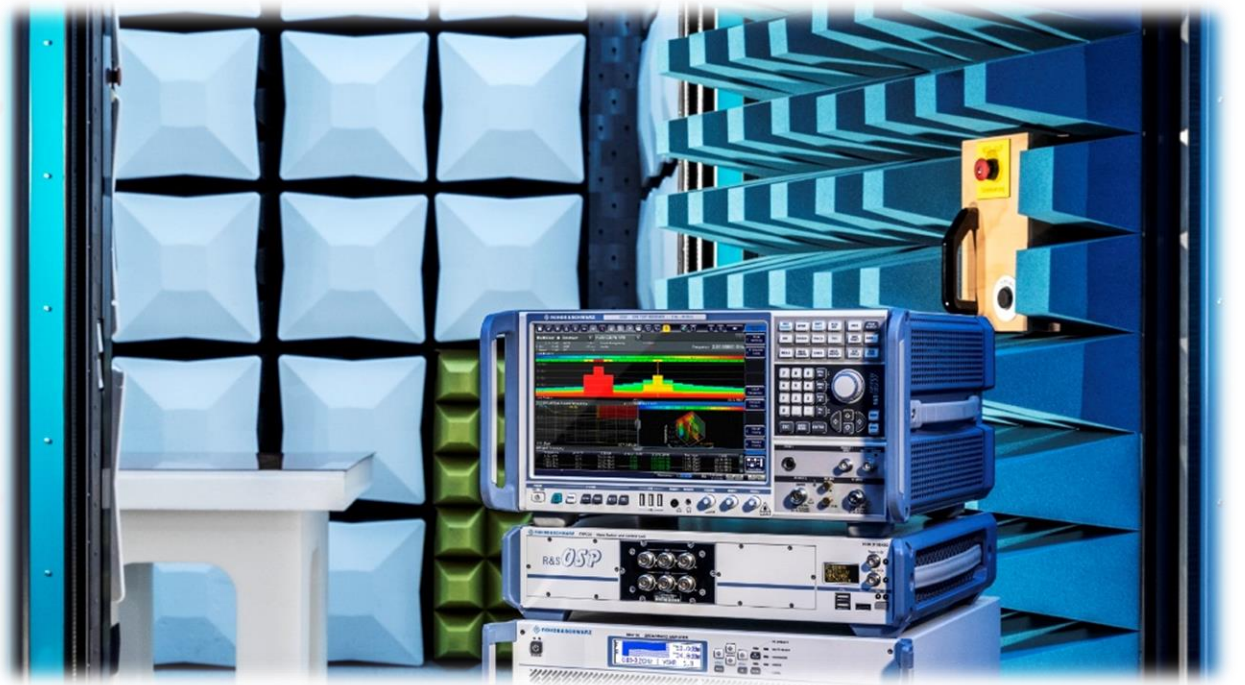
Nature of Electromagnetic Environment (EME) and Working Volume

EME

- ▶ In a properly operated RC, statistically the EME is isotropic, randomly polarized, and uniform (constant field amplitude) within some variable and predictable uncertainty

Working Volume

- ▶ All the volume $\sim \lambda/2$ (at LUF) from walls, floor and ceiling
 - Common guideline (conservative for most chambers) is 1m from wall, floor and ceiling



FULL COMPLIANCE – EVERYTHING ELSE

What is Full Compliance Testing ?

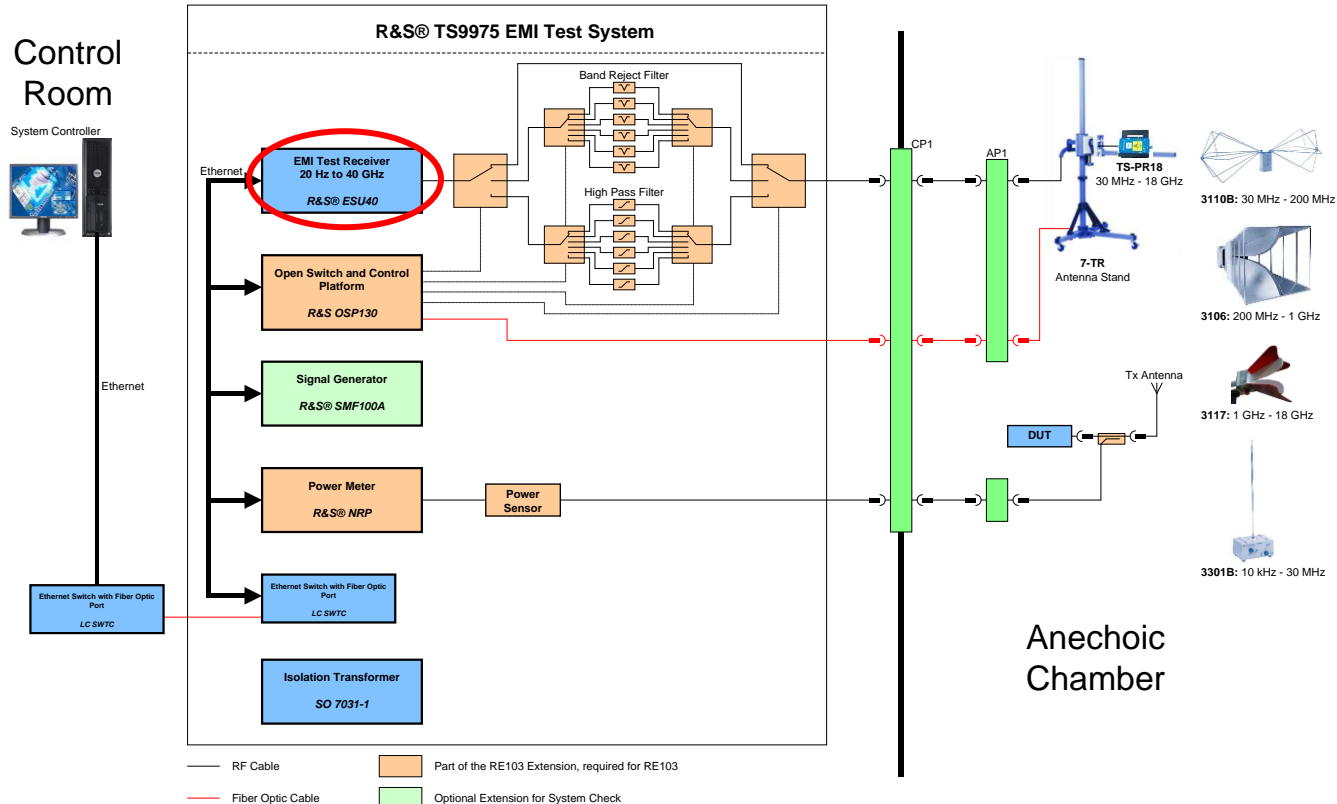
- ▶ Formal testing process that is typically conducted in an accredited EMC testing lab.
- ▶ The purpose of full compliance testing is to ensure that electronic devices meet certain regulatory standards for electromagnetic emissions and immunity.
- ▶ It is much more rigorous than pre-compliance testing and involves a wider range of tests and measurements. This type of testing is required before electronic devices can be sold in certain markets if the standard or country calls for it.
- ▶ It also requires specialized test equipment
 - Remember test time translates to \$
 - At the core of compliance test, one would prefer not only the widest dynamic range, highest accuracy, and lowest noise available, but also any other options available to achieve fast and reliable tests in line with up-to-date test regulations.

Difference between Pre-Compliance Test and Full-Compliance Test

- ▶ Main difference between pre-compliance testing and full compliance testing is that,
 - Pre-compliance testing is a preliminary testing process that is conducted to identify potential EMC issues.
 - Full compliance testing is a formal testing process conducted by an accredited EMC testing lab. This ensures that electronic devices meet strict regulatory standards for electromagnetic emissions and immunity.
- ▶ While pre-compliance testing can help manufacturers catch and address EMC issues early on, it can also be used to make the Declaration of Conformity, as most standards do not call for full compliant EMC testing. Full compliance testing is necessary to ensure that electronic devices meet regulatory requirements and can be sold in certain markets.
- ▶ Both types of testing are important for ensuring that electronic devices are safe, reliable, and compliant with regulatory standards.

Example: RE103 Test Setup

- ▶ Antenna spurious and harmonic outputs, 10 kHz to 18 GHz



Signals in EMC

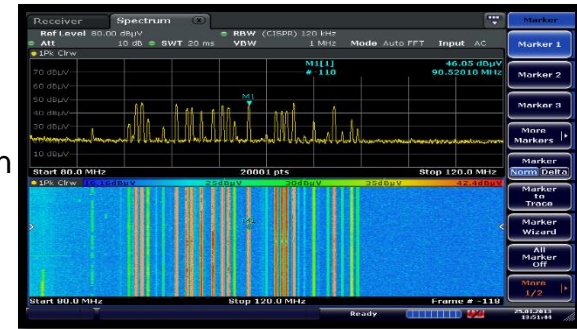
- ▶ Discrete (interference) frequencies
 - Static. Continuous wave (CW)
 - Harmonics
- ▶ Modulated
 - Pulse-modulated
 - Amplitude- or frequency modulated
 - Intermittent
- ▶ Transients
 - Dynamic
 - “No pattern”, e.g. temperature or SW controlled
- ▶ Noise
 - Stochastic signals



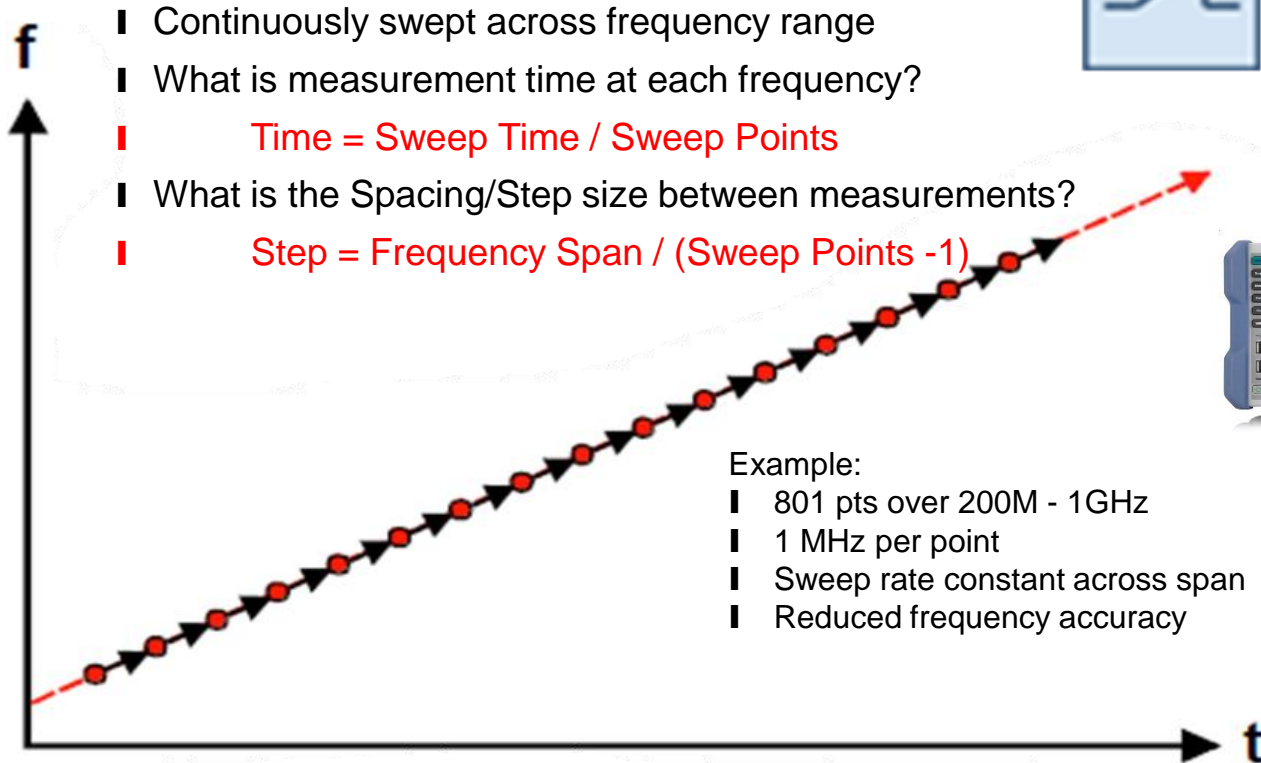
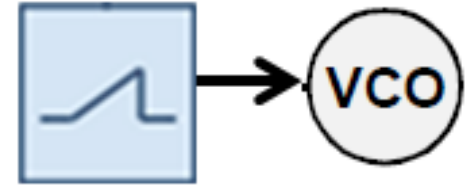
And all combinations ...

EMI Receivers

- ▶ Full-compliance tests are time consuming and expensive
- ▶ If the measurements can be made faster without sacrificing accuracy, there is a huge cost saving
- ▶ **EMI receivers** make such measurements possible
 - Faster and more reliable than ever
 - Highest dynamic range and level accuracy
- ▶ Configurable pre-selection
 - High sensitivity with a built-in preamp of 20dB gain
 - Built-in pre-selection filters optimized to the requirements of a speedy time domain scan
 - Special filters such as 150 kHz HP, 2 MHz HP and notch filters for ISM bands suppression
- ▶ Real-time analysis
- ▶ Spectrogram view for diagnostics and debugging measures



Spectrum Analyzers “Sweep”



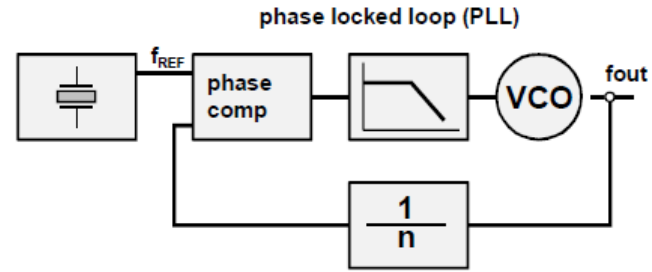
- Continuously swept across frequency range
- What is measurement time at each frequency?
 - $\text{Time} = \text{Sweep Time} / \text{Sweep Points}$
- What is the Spacing/Step size between measurements?
 - $\text{Step} = \text{Frequency Span} / (\text{Sweep Points} - 1)$

Example:

- 801 pts over 200M - 1GHz
- 1 MHz per point
- Sweep rate constant across span
- Reduced frequency accuracy



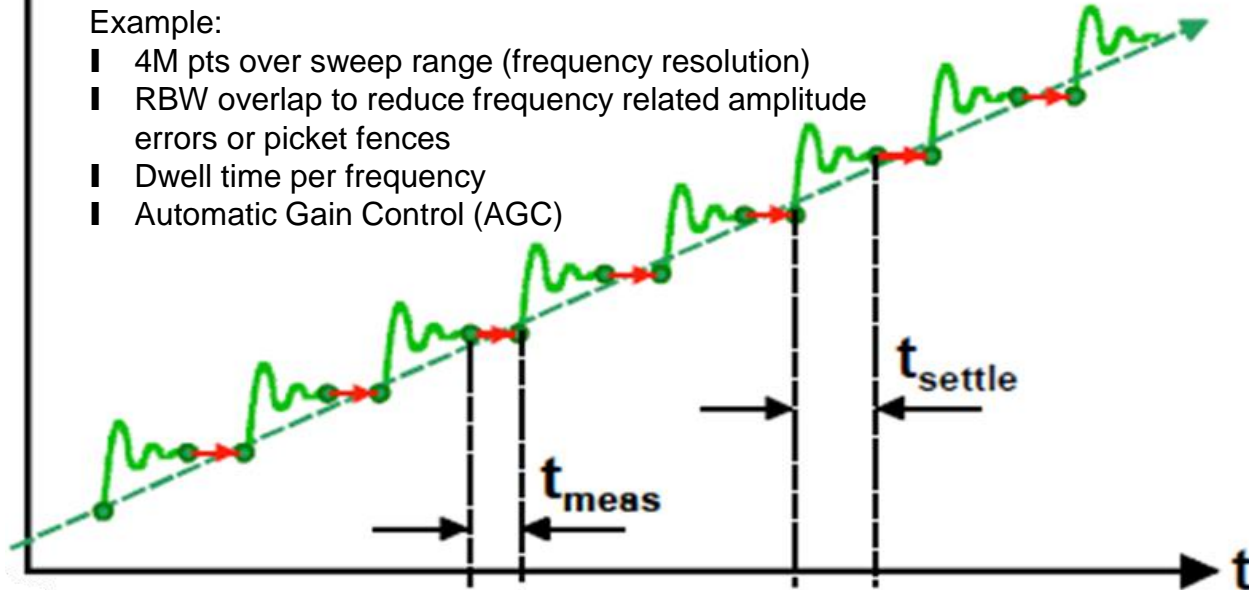
EMI Test Receivers “Scan”



- ┆ Tuned (stop) at each point
- ┆ Directly set the **measurement time**
- ┆ Directly set the **step size**

Example:

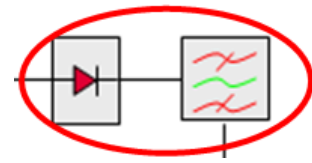
- ┆ 4M pts over sweep range (frequency resolution)
- ┆ RBW overlap to reduce frequency related amplitude errors or picket fences
- ┆ Dwell time per frequency
- ┆ Automatic Gain Control (AGC)



Receivers – Advantages

- ▶ Detectors
- ▶ RBW
- ▶ Pre-Selection
- ▶ Time domain scan
- ▶ Real-time Spectrum Analysis

Detectors



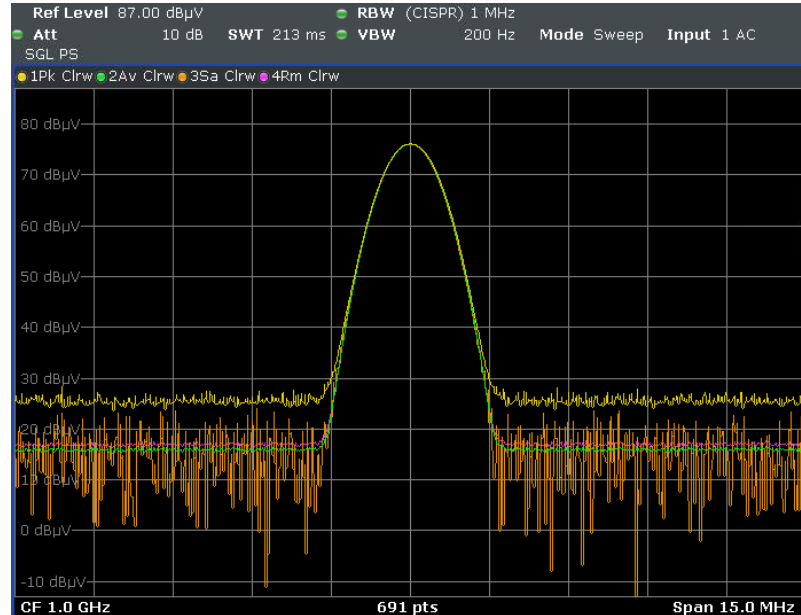
■ All detectors are designed to provide the same results for a pure sine wave input (CW, not modulated, not pulsed)

■ Common SA detectors 3dB

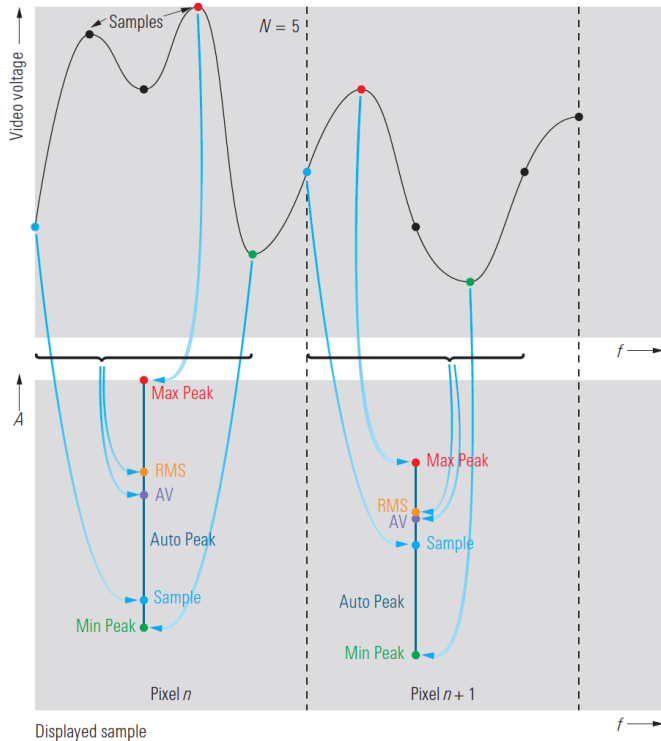
- Peak
- Sample
- RMS
- Average

■ Common EMI detectors 6dB

- Peak
- Quasi-Peak
- CISPR RMS
- CISPR Average



Detectors you'll find in Spectrum Analyzers

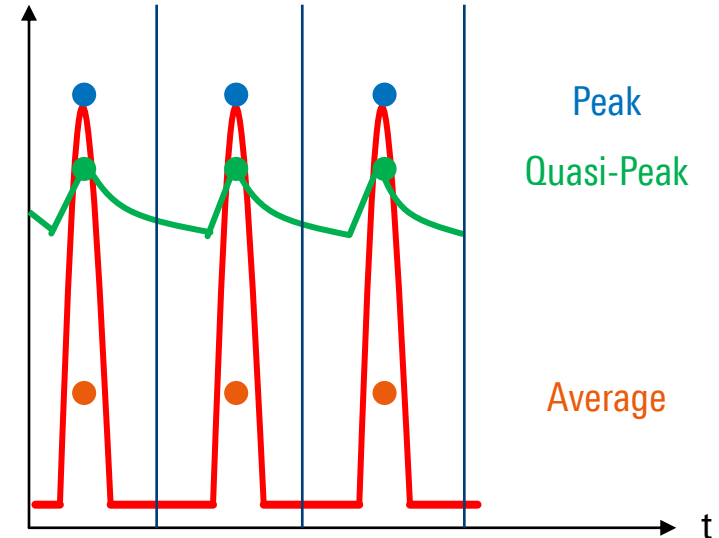


Fundamentals of Spectrum Analysis
Christoph Rauscher,
Rohde & Schwarz eBook edition 2012

- Max Peak
- Min Peak
- Sample
- Average (AV)
- RMS

DETECTORS

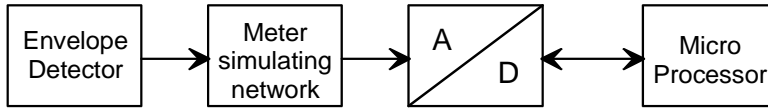
- ▶ Detectors determine how values measured over an interval are combined into a single value
 - Peak: maximum value
 - Quasi-peak: measures the “annoyance” of a signal
 - Average: average value
- ▶ Compliance often uses quasi-peak
 - But precompliance tends to use peak detector
- ▶ Peak is much faster than quasi-peak
- ▶ Peak levels are always higher than quasi-peak
 - If signals are below limits with peak, they will always be below limit with quasi-peak



Difference between Average and CISPR Avg

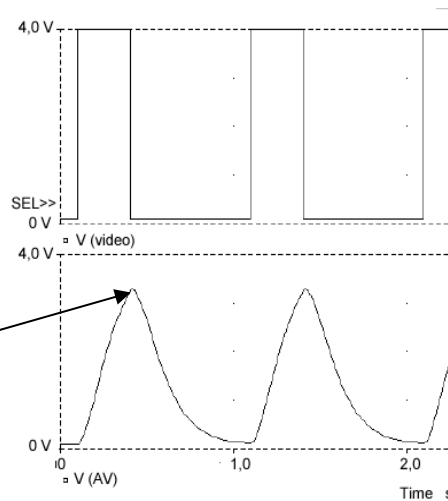
Linear CISPR-Average detector with meter time constant

- 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

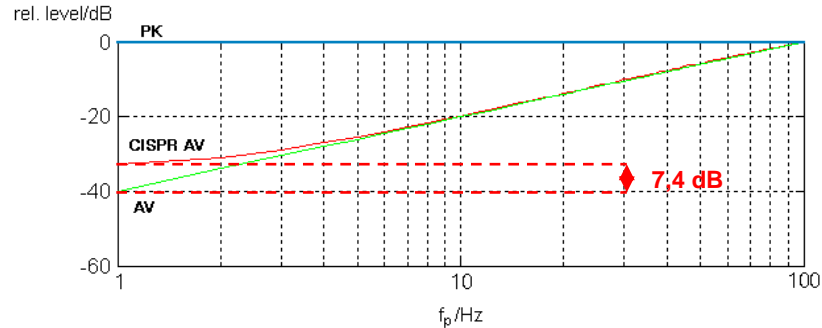


Difference between Average and CISPR Avg

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

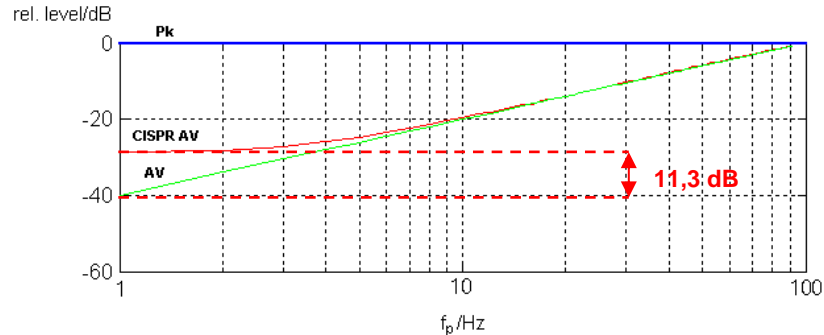
Band A/B:

$T_{\text{meter}} = 160 \text{ ms}$



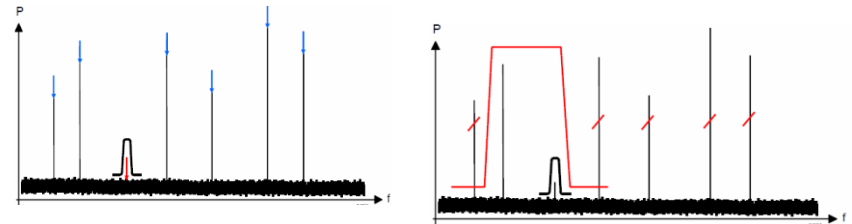
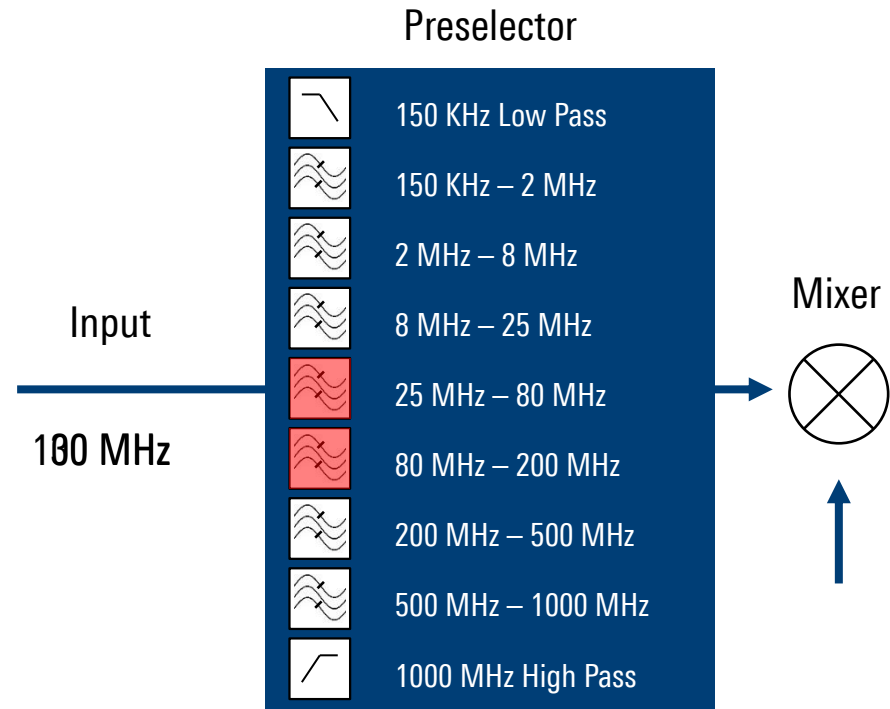
Band C/D/E:

$T_{\text{meter}} = 100 \text{ ms}$



PRESELECTION

- ▶ Input signal is not known / controllable
- ▶ Out of band signals could overload the mixer
 - Causing compression or distortion and therefore invalid results
- ▶ Preselection protects the first mixer
 - Filters the inputs signal to select only the frequencies of interest
 - Automatically configured by receiver
- ▶ Many EMI standards require preselection
 - Compliance testing performed using receivers
 - Spectrum analyzer “preselection” is usually simply (YIG) high-pass filtering

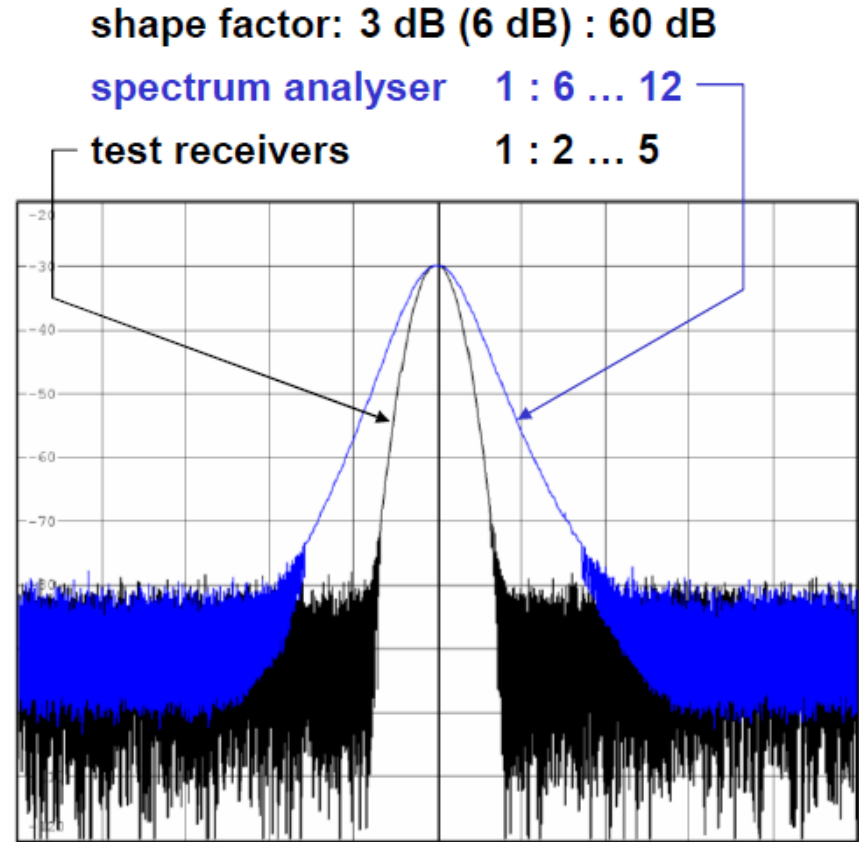


Video Demonstrating Effects of Pre-selection



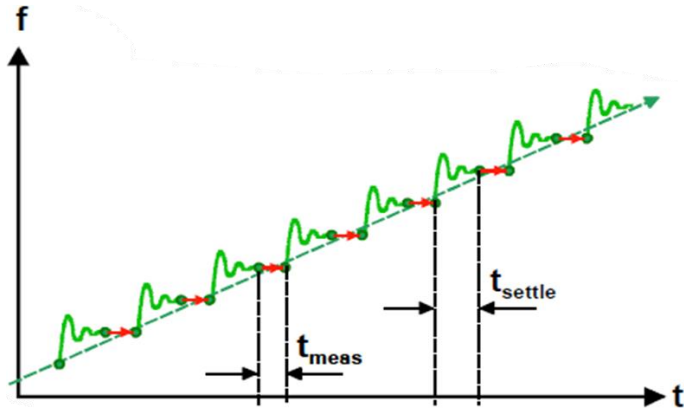
Resolution Bandwidth

- ▶ What is RBW?
 - Qualitative measure of the minimum separation required between two frequency components to be able to visually separate them
- ▶ SA 3 dB vs. EMI 6 dB
- ▶ EMI Receivers have a more selective RBW
 - Helps isolate emissions
 - Requires more test time

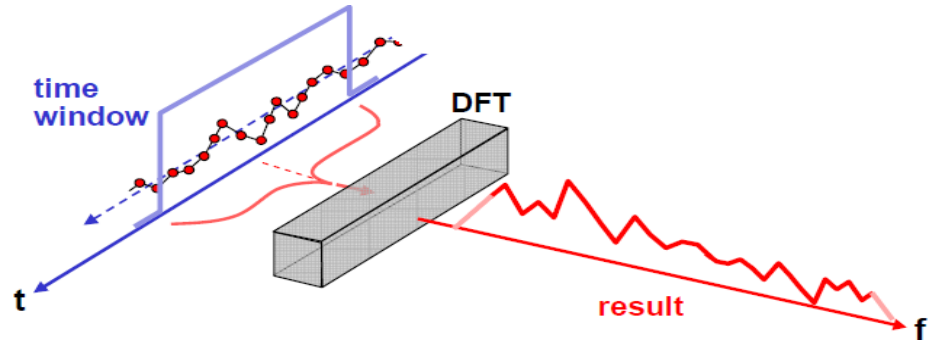


TIME DOMAIN SCAN

- Time Domain Scan** is a Fast Fourier Transform (FFT)-based measurement that can save a significant amount of measurement time vs. classic stepped scans

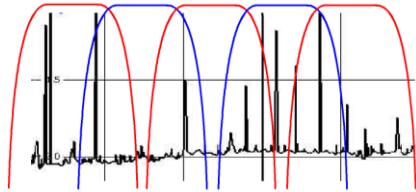


Classic stepped scan



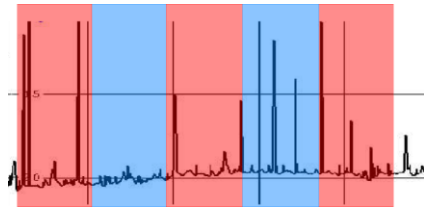
Time Domain Scan (FFT-based)

FFT-based Test Receiver



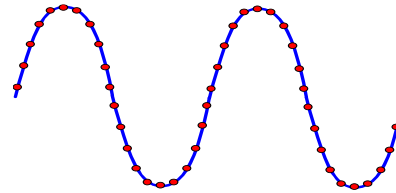
Frequency range

Split the measured frequency range in consecutive frequency intervals



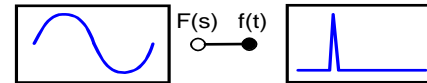
Frequency domain

Merging the spectral distributions of all frequency blocks



Time-domain

Sampling of the filtered signals with high sampling rate/resolution and windowing



Fast-Fourier transform

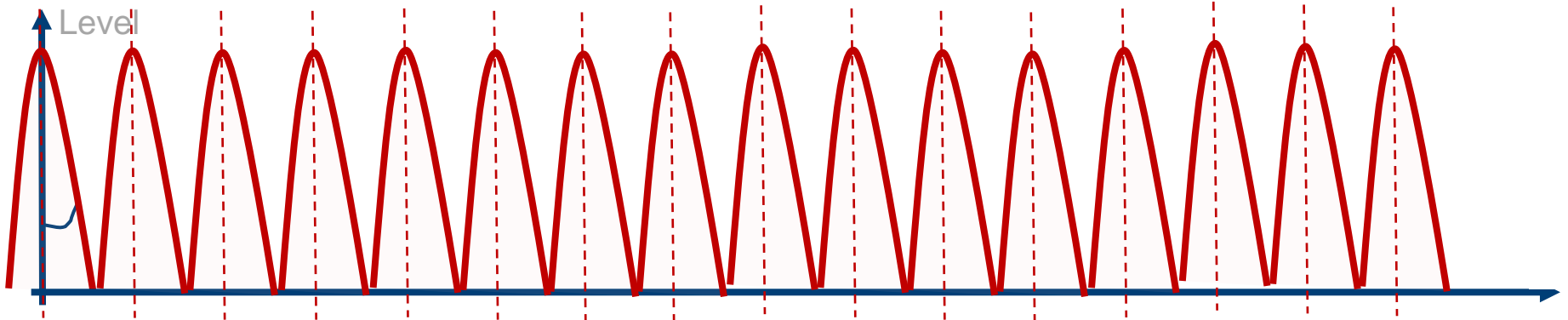
Signal transformation of the filtered signals from time to frequency domain in blocks



SWEEP

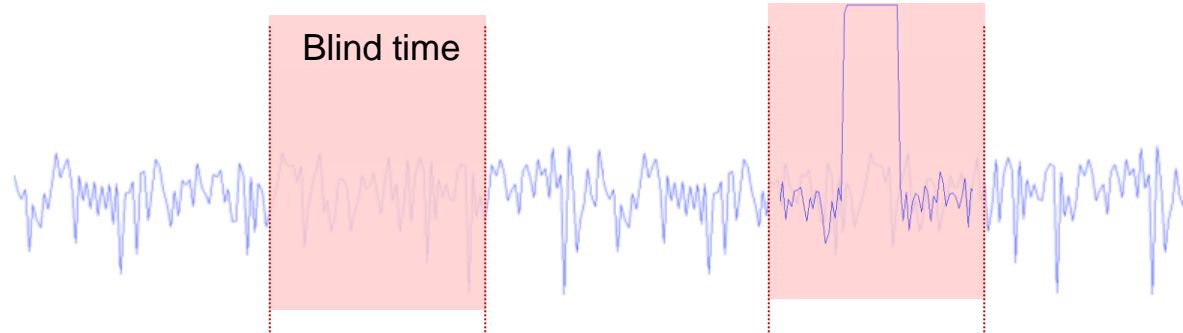


STEPPED SCAN



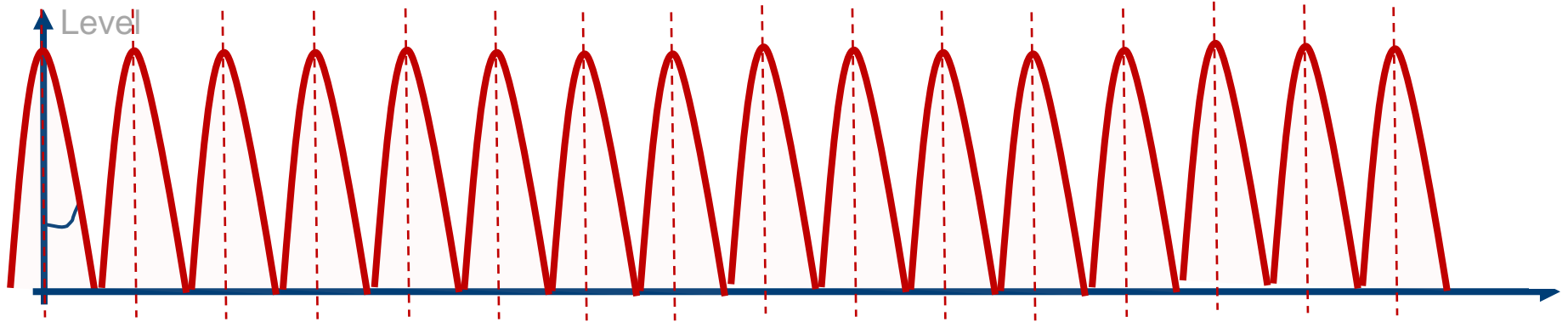
Blind Time

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

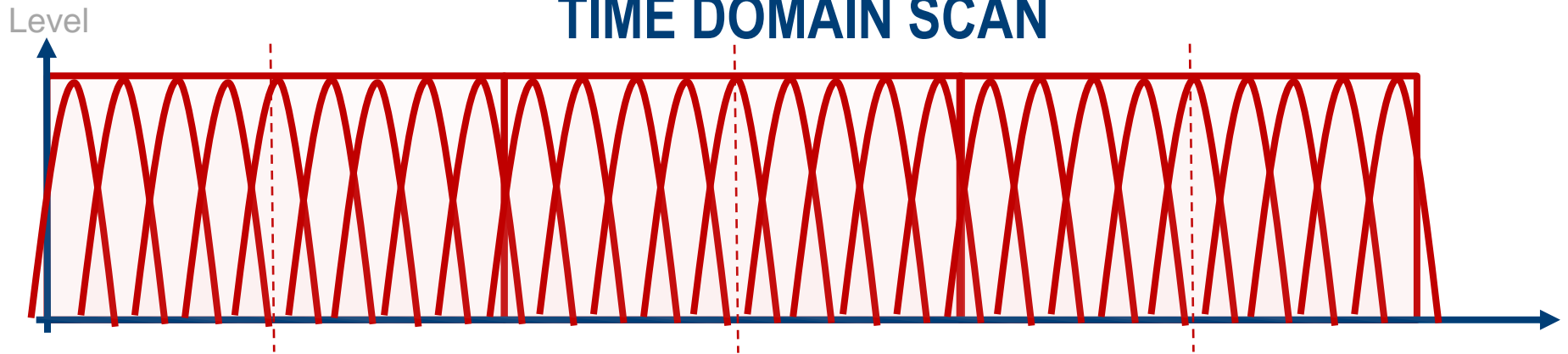


“for EMI measurements, FFT-based measuring instruments shall sample and evaluate the signal continuously during the measurement time”

STEPPED SCAN



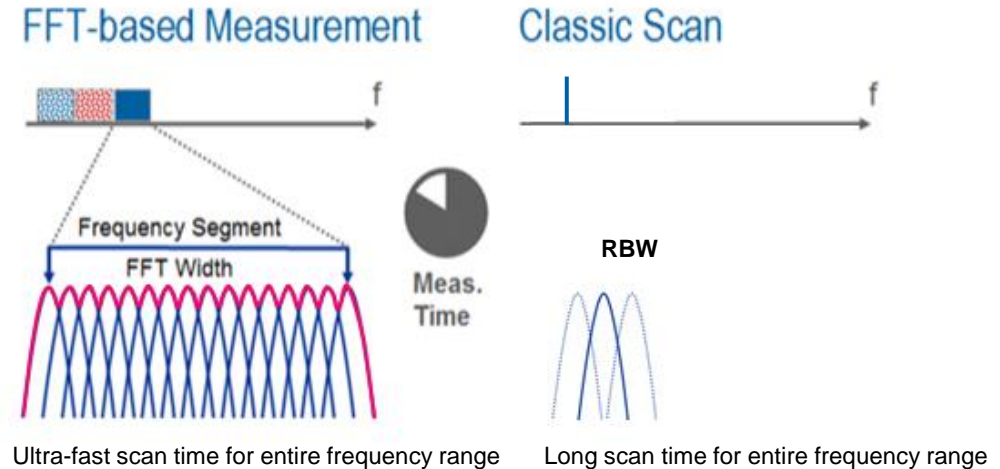
TIME DOMAIN SCAN



Motivation for FFT-based measuring receivers

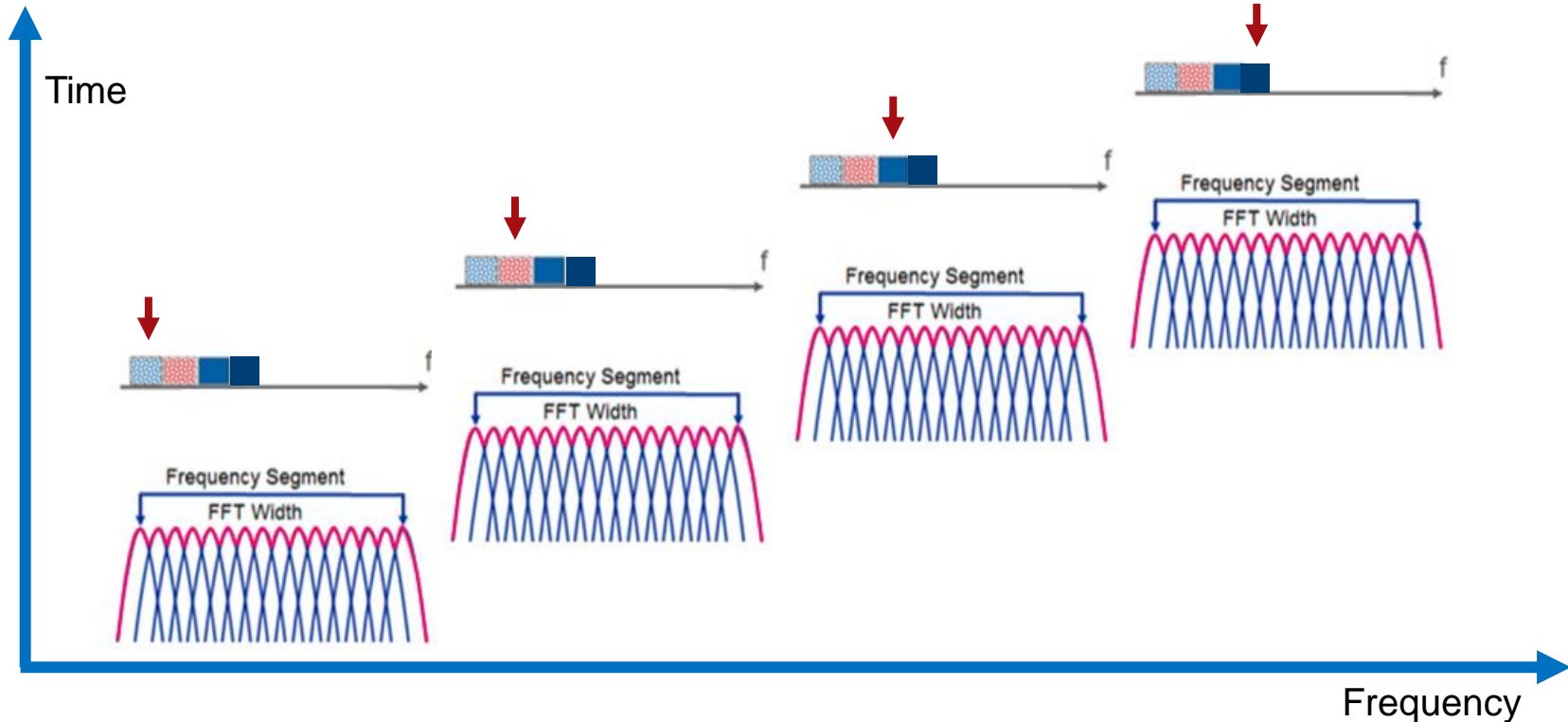
- ▶ **More Speed** – FFT-based receivers are measuring spectral segments much wider than the resolution bandwidth during the measurement time by parallel calculation at several frequencies

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



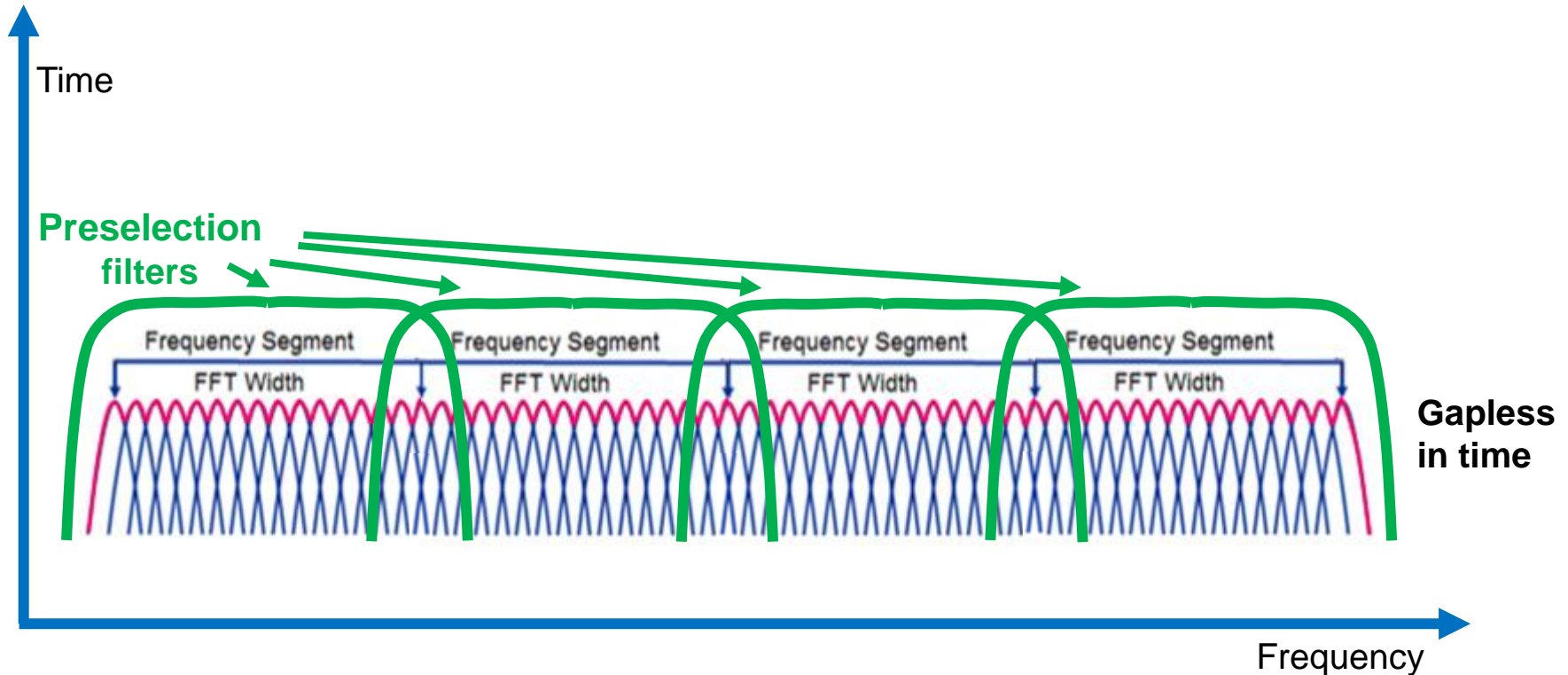
Motivation for FFT-based measuring receivers

Consecutive measured FFT-Segments if Span > FFF Width

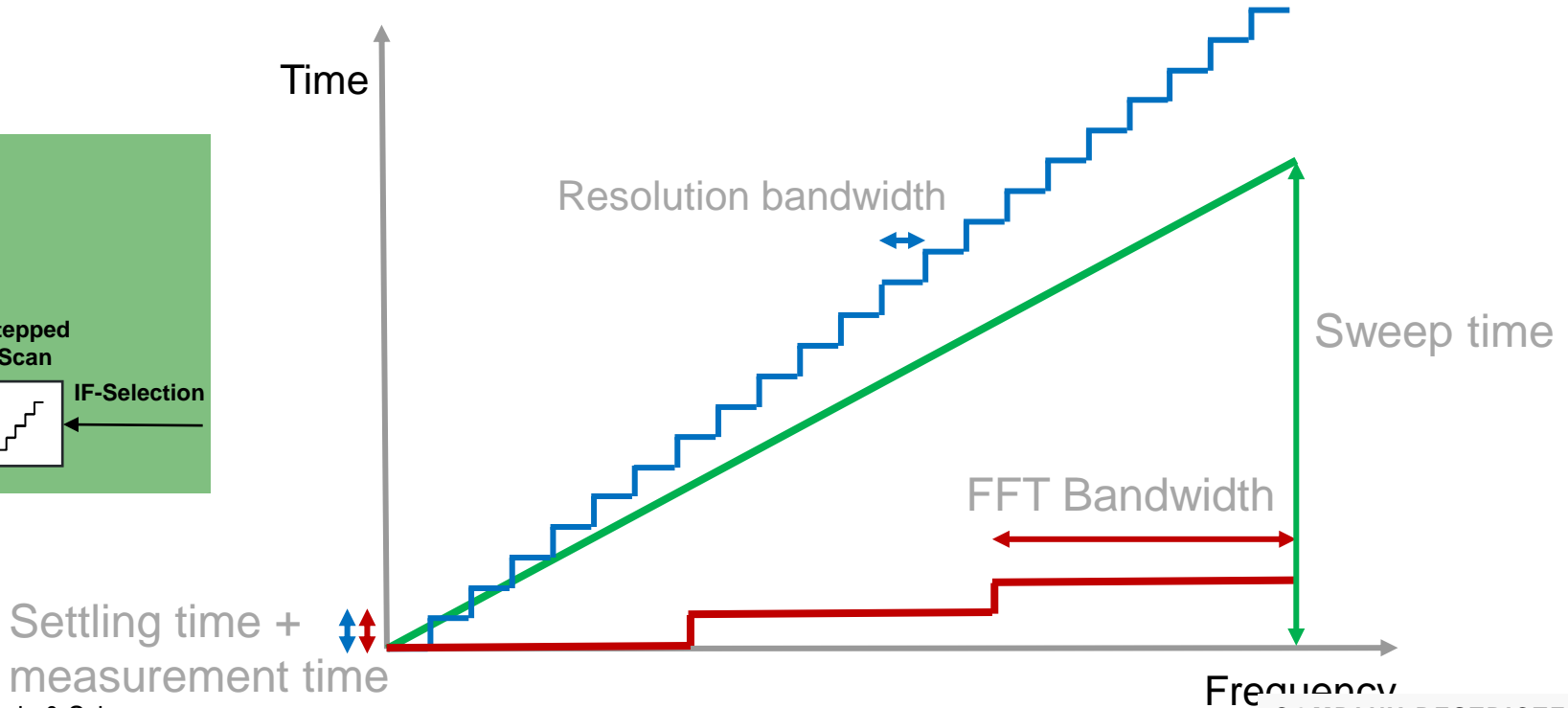
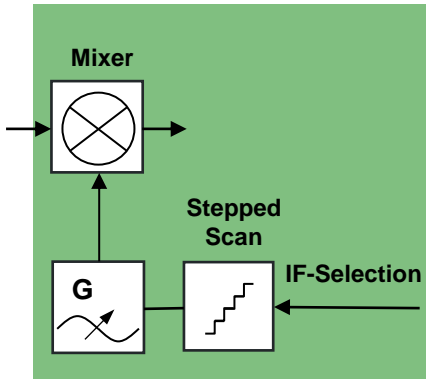


Motivation for FFT-based measuring receivers

Parallel measured FFT-Segments

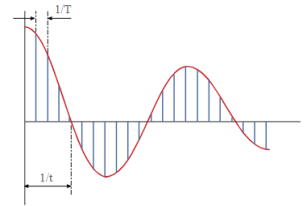
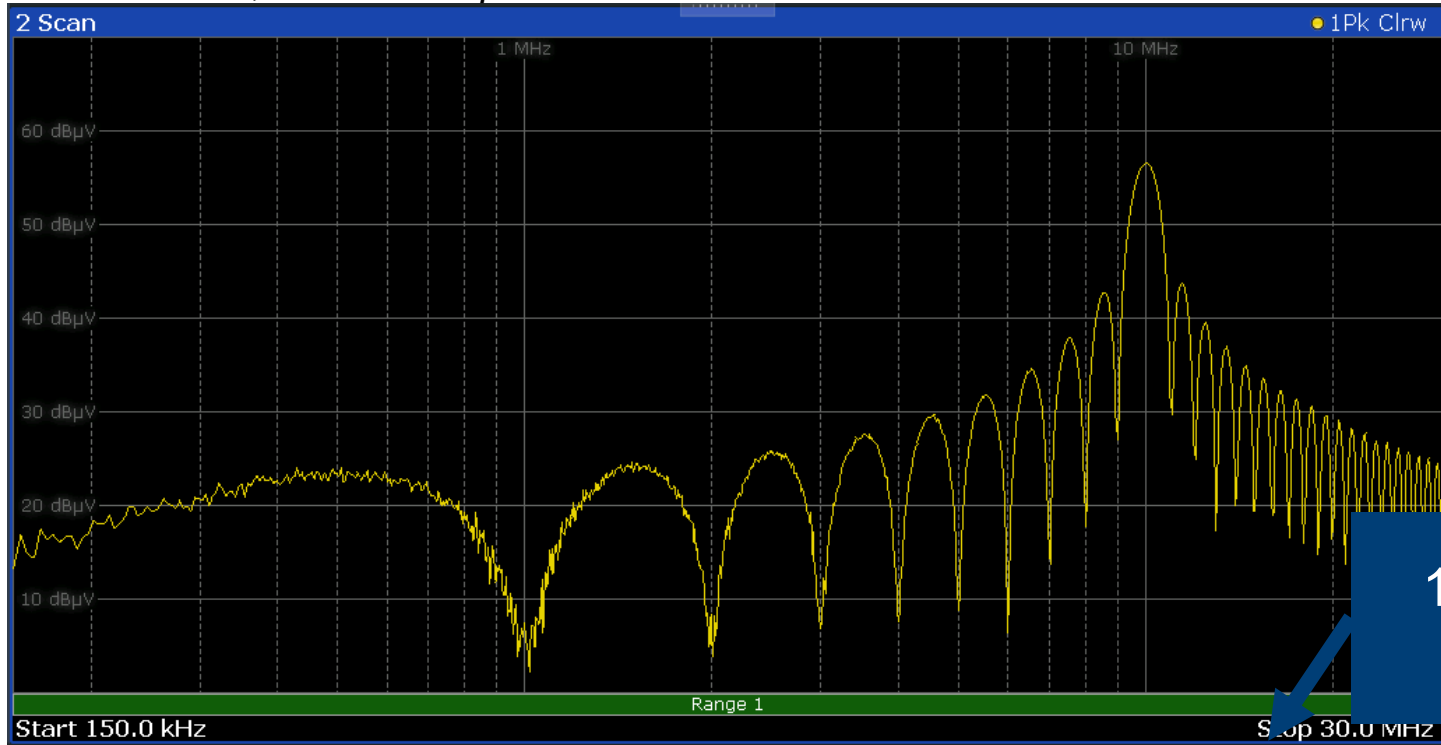


SWEEP / STEPPED SCAN / TIME DOMAIN SCAN



Time Domain Scan @ 2 ms Measurement time

Period: 2 ms, Duration: 1 μ s



$$1/T \approx 500 \text{ Hz}$$
$$T = 1 \mu\text{s}$$

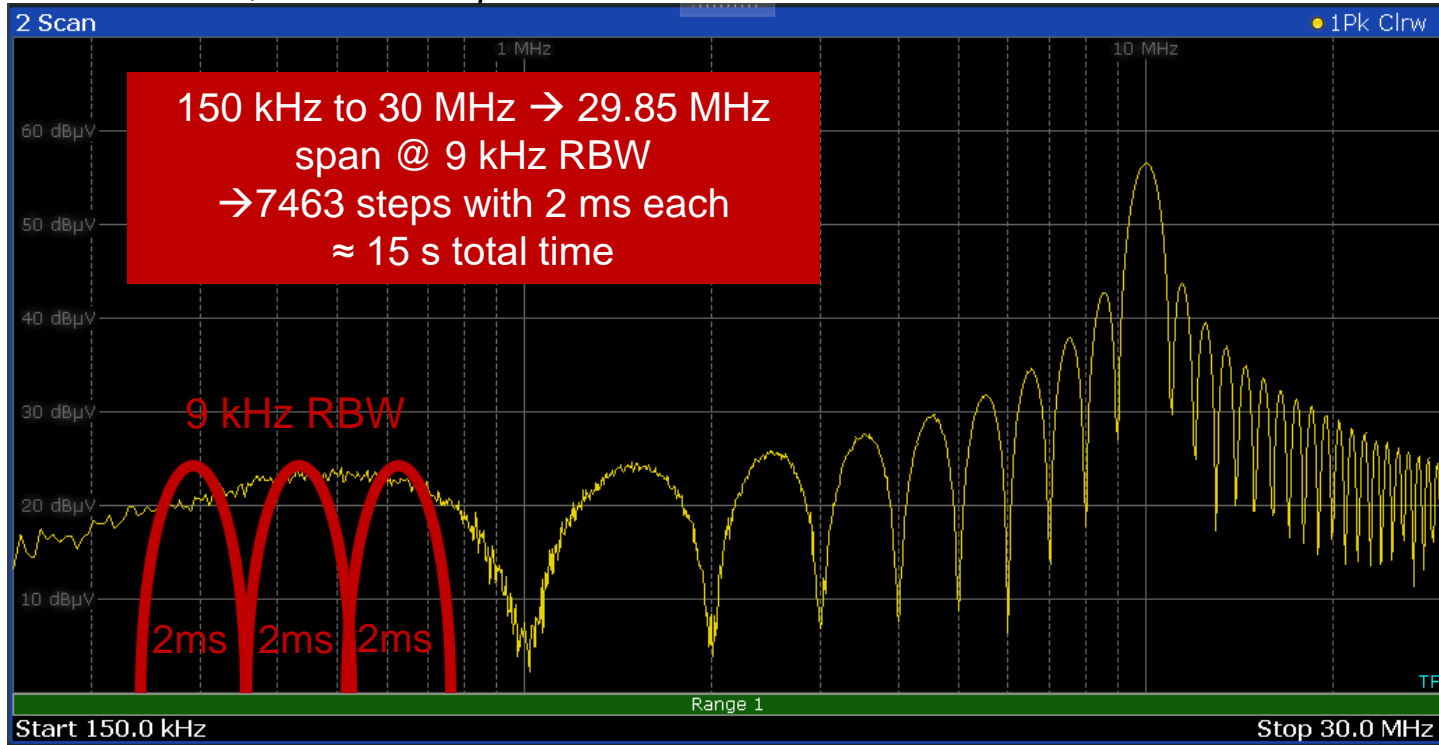
Stepped scan @ 1 ms Measurement time

Period: 2 ms, Duration: 1 μ s



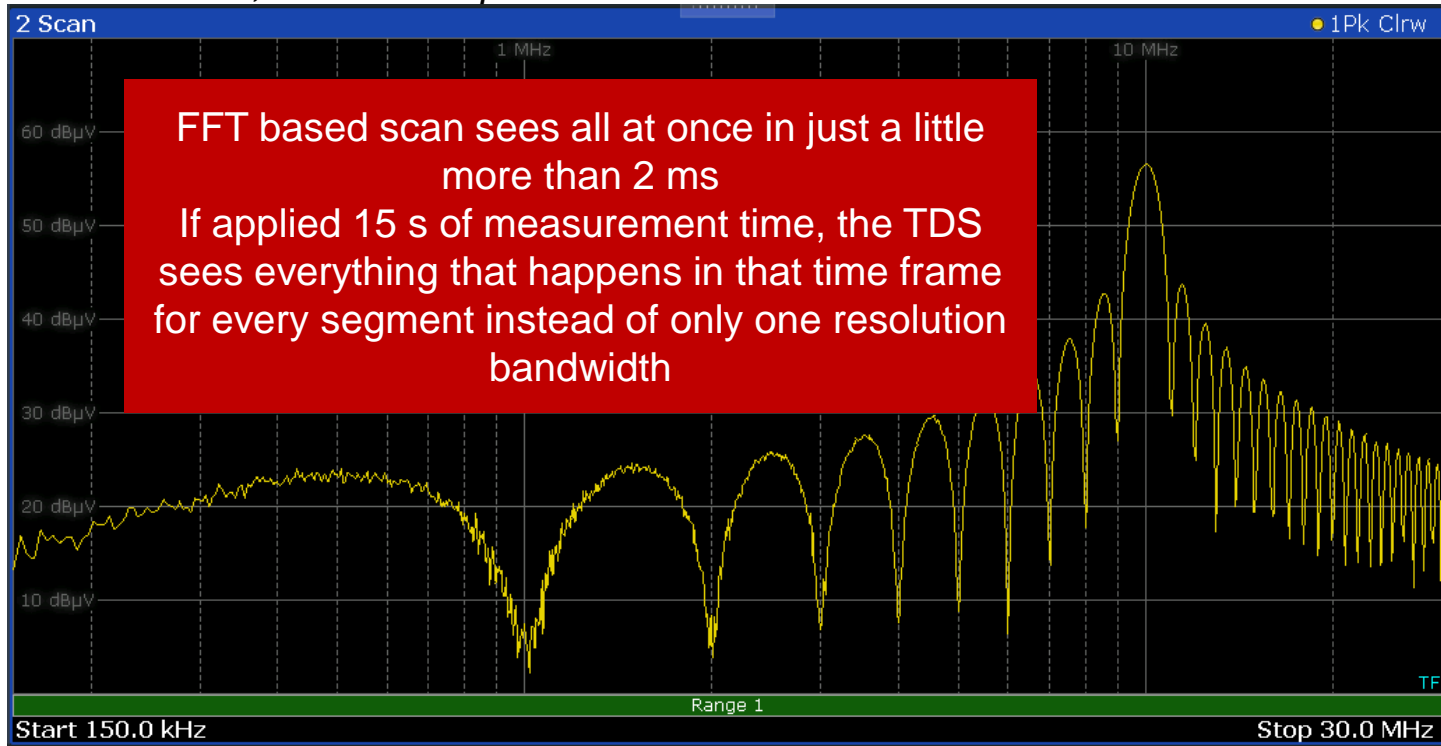
Stepped scan @ 2 ms Measurement time

Period: 2 ms, Duration: 1 μ s



Time Domain Scan @ 2 ms Measurement time

Period: 2 ms, Duration: 1 μ s



Example 1

Scan spectrogram and wideband FFT practical use

Vehicle Wakes UP

(Open via Remote Key)

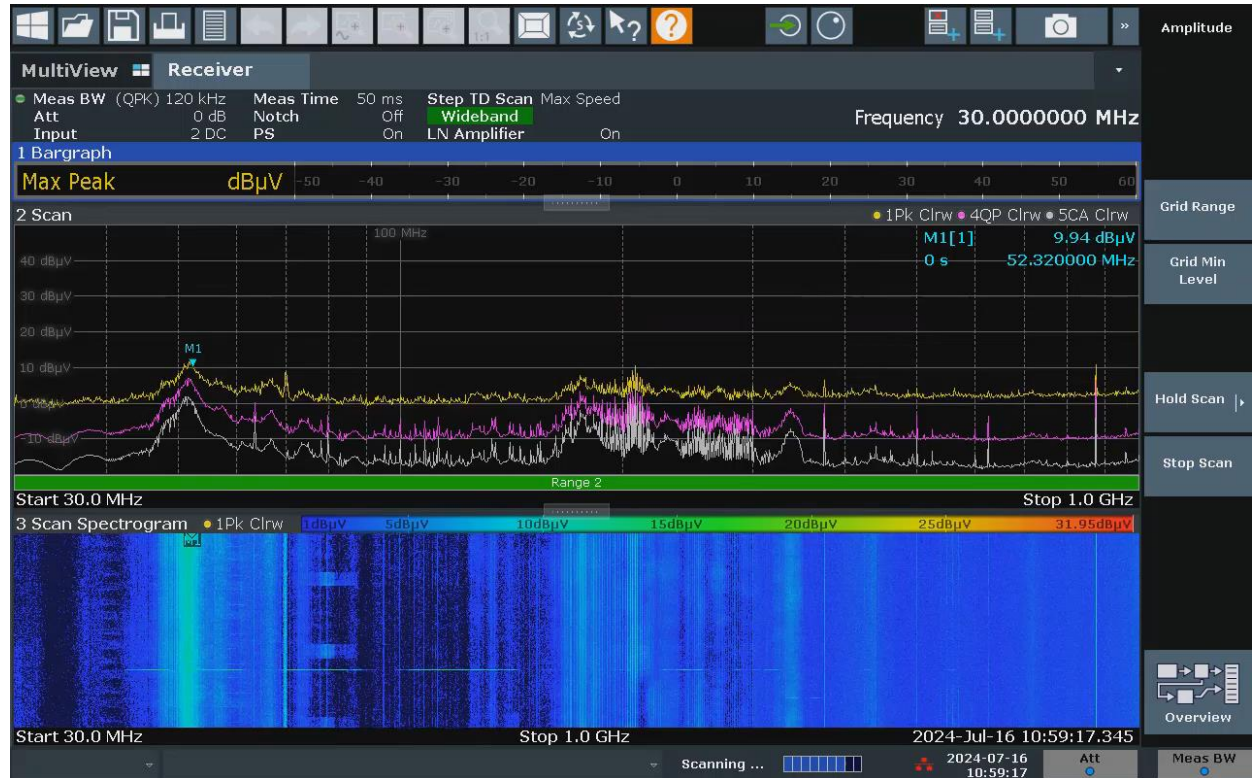
- ▶ First you see Remote Key communication ~433MHz
- ▶ Complete Vehicle/Board Network is waking up immediately afterwards. Broadband Emission occur over the whole Frequency Band.



Example 2

Scan spectrogram and wideband FFT practical use

Honking 3 x Times



Example 3

Scan spectrogram and wideband FFT practical use

Electric Vehicle accelerating and braking in cycles.

- ▶ Up to 100MHz high dynamic Emission changes, due to different load condition during accelerating and break.
- ▶ Additional different control algorithms are applied for these conditions which you see in the shape changes of Emissions.
(WITH PEAK MAXHOLD)



Rohde & Schwarz offers the complete portfolio for EMC test



EMI test receivers



**EMC test software
ELEKTRA, AdvISE**



**Broadband
amplifiers**



EMC test systems



EMC accessories



**Signal and
spectrum analyzers**



Oscilloscopes



Signal Generators



TURN KEY SYSTEMS FROM R&S

Full Turn-Key Systems

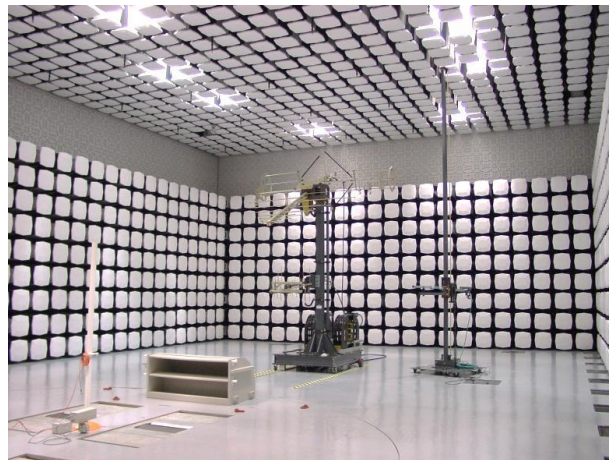
TPIC – Texas Production and Integration Center

I Provides and supports turnkey systems and solutions in the fields of:

- I Electromagnetic Compatibility (EMC)
- I Wireless Test Systems
- I Radio Communication
- I Coverage Measurement Systems
- I General RF
- I Automotive

I System Support Center

- I 13,000 sqft facility just north of the DFW airport in Dallas, TX
- I Full-service RF Test Solutions provider for the Americas
- I State of the art manufacturing of test systems
- I All major integration parts (racks, mounting hardware etc.) in stock



Rohde & Schwarz Turnkey Solution - TS9975

Conducted and Radiated Emissions EMC Test System

- **Fully Integrated Solution from One supplier** - From system design and implementation to installation and training, these turnkey systems and our EMC experts provide everything from a single source, enabling the customer to concentrate on testing.
- **Main Features**
 - Fully Automatic Emissions Test System up to 40GHz
 - Conducted EMI measurements from 0.15 MHz to 30 MHz
 - Radiated EMI measurements from 30 MHz to 40 GHz
 - System automation via automatic path switching
 - Equipment for system calibration and system check is included
- **System configuration** The system features a highly modular hardware and software concept. Customized systems can be configured from a variety of instruments. The system is a complete package of hardware, user-friendly software, system services and installation. Users can very quickly learn to use the system.
- **Generic name TS9975** for ALL EMI Test Systems (pre-compliance and full compliance)

Commercial standards

- CISPR11 to 32
- IEC/EN55011 to IEC/EN55032
- ANSI-C63.4
- FCC Part 15, Part 18
- 2014/30/EU
- Customer-specific requirements
- IEC60601-1-2 Edition 4.0

A&D standards

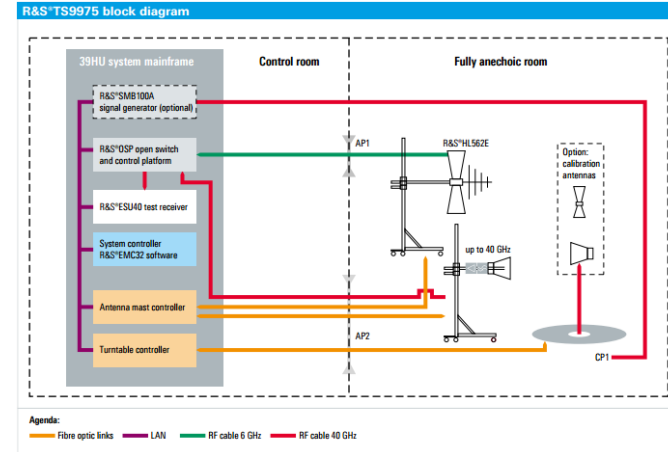
- MIL-STD-461/464
- RTCA DO160
- Country-specific requirements
- Customer-specific requirements

Automotive standards

- CISPR12
- CISPR25
- UN/ECE R10
- Customer-specific requirements

Wireless Standards

- ETSI EN 301489 for all major technologies(e.g. CDMA, GSM, UMTS, LTE, WLAN, WiMAX etc.)
- 3GPP TS 51.010
- ETSI EN 301908-1
- ETSI EN 300328-1



System Components: anechoic chamber, remote controlled turntable, automatic antenna mast, control hardware, test receiver, accessories (antennas, LISN's, probes, current clamps...), filter unit (only for mobile comm devices), communications tester (only for mobile comm devices), EMC32 control software.

Rohde & Schwarz Turnkey Solution - TS9981 Radiated Immunity Test System

- **Fully integrated all in one solution for radiated EMS measurements** - From system design and implementation to installation and training, these turnkey systems and our EMC experts provide everything from a single source, enabling the customer to concentrate on testing.
- **Configurations to meet your needs** - Due to its modular design, it covers a wide range of applications and can be very easily adapted to the measurement task at hand. Any configuration is possible with a compact test cell (GTEM / TEM) to the accredited test system for complete motor vehicles with 200 V/m. Typical configuration include:
 - 80 MHz to 1, 3 or 6 GHz for commercial test systems
 - 200 MHz to 3.1 GHz or 18 GHz for automotive
 - 10 kHz to 40 GHz for MIL-STD-461 / 462
 - Most common field strengths are 3, 10, 200 V/m
- **Fully controlled by ELEKTRA** - All test systems are controlled by R&S®ELEKTRA EMC test software with its various capabilities like extensive EUT- and system monitoring.

Commercial standards

- IEC/EN 61000-4-3
- IEC/EN 61000-4-20
- CISPR 24/EN 55024
- CISPR 35/EN 55035
- EN 60601-1-2

A&D standards

- MIL-STD-461/464

Automotive standards – components

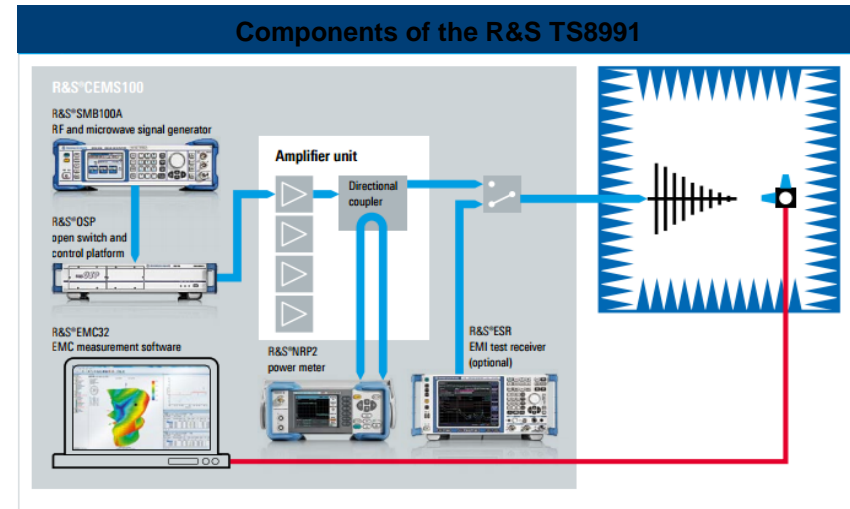
- ISO 11452
- 2004/104/EC
- SAE J1113

Automotive standards – vehicles

- ISO 11451
- 2004/104/EC
- SAE J551

Wireless Standards

- ETSI EN 301489 for all major technologies(e.g. CDMA, GSM, UMTS, LTE, WLAN, WiMAX etc.)



System Components: anechoic chamber, remote control turntable (optional), signal generator, power meter, control hardware, amplifiers, accessories, communications tester(only for mobile comm devices), EMC32 control software

Rohde & Schwarz Turnkey Solution - TS9986 Conducted Immunity Test System

- Fully integrated all in one solution for conducted EMS measurements** - From system design and implementation to installation and training, these turnkey systems and our EMC experts provide everything from a single source, enabling the customer to concentrate on testing.
- Modular design and flexibility** - Due to its modular design, it covers a wide range of applications and can be very easily adapted to the measurement task at hand. Any configuration is possible to cover commercial, MIL-STD and Automotive Testing
- Automatic Control** - All test systems are controlled by R&S®ELEKTRA EMC test software with its various capabilities like extensive EUT- and system monitoring.

System Components: Shielded room (optional), signal generator, power meter, spectrum analyzer / receiver for MIL STD, control hardware, amplifiers, accessories (CDN's, injection probes, current clamps), communication tester (only for mobile comm devices), ELEKTRA control software.

Commercial standards

- IEC/EN 61000-4-6
- CISPR 24/EN 55024
- EN 60601-1-2

A&D standards

- MIL-STD-461

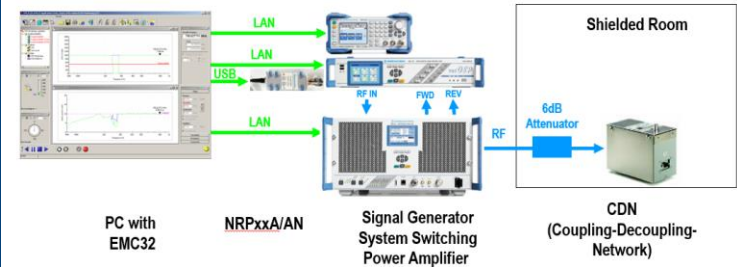
Automotive standards – components

- ISO 11452
- 2004/104/EC
- SAE J1113

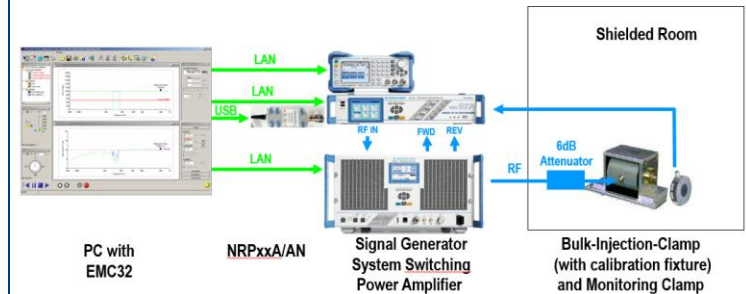
Wireless standards

- ETSI EN 301489 for all major technologies (e.g. CDMA, GSM, UMTS, LTE, WLAN, WiMAX etc.)

Application example for conducted susceptibility measurements according to IEC 61000-4-6 Coupling Network (CDN)

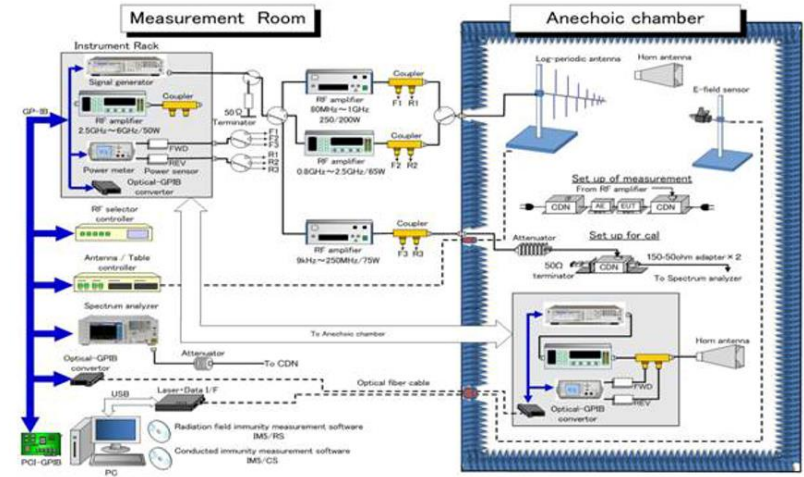


Application example for conducted susceptibility measurements according to IEC 61000-4-6 Current Clamp (BCI)



Rohde & Schwarz Turnkey Solution - TS9982 Conducted and Radiated Immunity Test System

- Fully integrated all in one solution for conducted and radiated EMS measurements** - From system design and implementation to installation and training, these turnkey systems and our EMC experts provide everything from a single source, enabling the customer to concentrate on testing.
- Modular design and flexibility** - Due to its modular design, it covers a wide range of applications and can be very easily adapted to the measurement task at hand. Any configuration is possible – from a small pre-compliance system with a compact test cell to the accredited test system for complete motor vehicles with 200 V/m.
- Automatic Control** - All test systems are controlled by R&S®ELEKTRA EMC test software with its various capabilities like extensive EUT- and system monitoring.



System components: anechoic chamber, remote control turntable (optional), signal generator, spectrum analyzer / receiver for MIL-STD, power meter, control hardware, amplifiers, accessories, communications tester (only for mobile comm devices, EMC32 control software)

Commercial standards

- IEC/EN 61000-4-3
- IEC/EN 61000-4-20
- CISPR 24/EN 55024
- EN 60601-1-2
- IEC/EN 61000-4-6

A&D standards

- MIL-STD-461

Automotive standards – components

- ISO 11452
- 2004/104/EC
- SAE J1113

Wireless standards

- ETSI EN 301489 for all major technologies (e.g. CDMA, GSM, UMTS, LTE, WLAN, WiMAX etc.)

Rohde & Schwarz Turnkey Solution - TS9983 Microwave EMS Test System 1 to 18 or 40 GHz

- **Fully integrated all in one solution for radiated EMS measurements above 6 GHz** - Due to its modular design, it covers a wide range of applications and can be very easily adapted to the measurement task at hand. This system will usually go up to 18 or 40 GHz. Field Strength for this system usually goes to 20 V/m or 200 V/m.
- **Custom designed by EMC systems experts** - The TS9983 was designed due to the higher loss / complexity of cables and antennas at higher frequencies. These losses require short and higher quality cables between the amplifier output and antenna.
- **Automatic Control** - All test systems are controlled by R&S®ELEKTRA EMC test software with its various capabilities like extensive EUT- and system monitoring.

Automotive standards – components

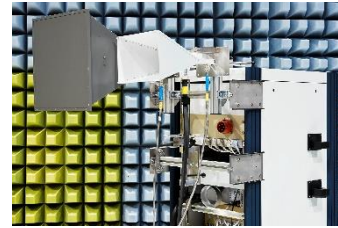
- ISO 11452
- 2004/104/EC
- SAE J1113

Automotive standards – vehicles

- ISO 11451
- 2004/104/EC
- SAE J551

A&D standards

- MIL-STD-461



System components:

anechoic chamber

- MIL STD - 461/464
- Automotive (CISPR25 / component)

Remote control turntable (optional), signal generator, power meter, control hardware, amplifiers, accessories (antennas, field monitoring probes), EMC32 control software.

Rohde & Schwarz Turnkey Solution – TS8997 Regulatory Test System for Wireless Devices

- **Fully integrated all in one solution for regulatory testing on wireless devices** - All wideband transmission systems in the 2.4 GHz and 5 GHz bands must be tested to verify compliance with ETSI EN 300 328 for the 2.4 GHz band and ETSI EN 301 893 for the 5 GHz band as well as **FCC §15.407 including DFS and FCC §15.247**. The latest versions of these standards require the use of special automated test procedures and test equipment. The R&S®TS8997 fully meets these requirements.

- **Key facts**

- Fast wideband power measurement that exceeds ETSI and FCC requirements
- Support for MIMO DUTs with up to 8 antenna ports
- Menu-driven, automatic measurements based on radio technology selected by the user
- Measurements via RF connection or antenna coupler
- Automated measurements with R&S®WMS32 GUI and software structure
- Automatic switching of test paths up to 40 GHz

- **Measures technologies typ. used in wideband devices e.g.**

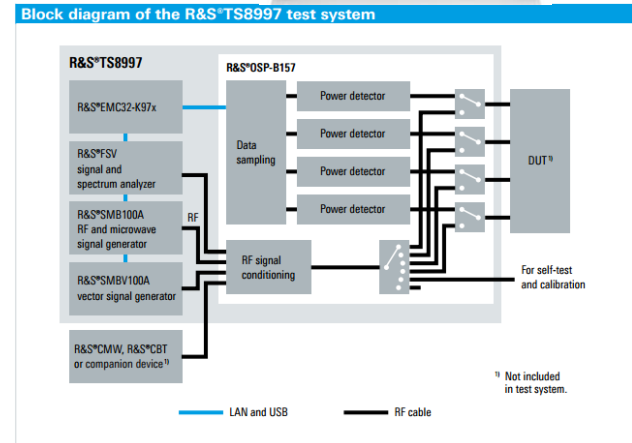
- WLAN 802.11a/b/g/n/ac
- Bluetooth®
- Wireless video transmission
- Radio remote control

Supported standards

- ETSI EN 300 328 v2.1.1 (RED)
- ETSI EN 301 893
- FCC §15.407 incl. DFS test cases
- FCC §15.247

Key tests

- DFS
- Adaptivity
- Receiver blocking
- Output power, PSD, spurious emissions,
- Occupied B/W, TOC occupancy, hopping sequence, Tx-sequence and many more tests...



Rohde & Schwarz Turnkey Solution - TS8991

WPTC – Wireless Performance or OTA – Over the Air Test System

- **Fully integrated all in one solution for wireless performance testing or also called Over-the-air (OTA) -** The R&S®TS8991 OTA performance test system measures the spatial radiation and sensitivity characteristic as specified by CTIA and 3GPP.
- **Key facts**
 - Measurement of OTA performance in line with CTIA, WiFi-Alliance, CWG, PTCRB standards and test cases
 - For all major cellular and non-cellular technologies, including A-GPS
 - Time-optimized, configurable test sequences for qualification and development, based on R&S®AMS32 system software
 - Can be combined with RSE radiated spurious emission test system (pre-compliant)
 - Turnkey solution with test instruments, system software, WPTC anechoic test chamber, OTA chamber and EUT positioner
 - Fast and cost-effective MIMO OTA decomposition test solution
- **WPTC Model Overview**



WPTC model overview					
	WPTC-XS	WPTC-S	WPTC-M	WPTC-L	WPTC-XL
Outer dimensions of shielding panels (L x W x H)	2.43 m x 2.43 m x 2.40 m	3.70 m x 3.10 m x 3.00 m	4.60 m x 3.70 m x 3.45 m	5.20 m x 4.30 m x 4.05 m	5.80 m x 5.20 m x 5.10 m
Frequency range of test chamber	0.7 GHz to 18 GHz	0.7 GHz to 18 GHz	0.7 GHz to 18 GHz	0.4 GHz to 18 GHz	0.4 GHz to 18 GHz
Typical range length	0.64 m	1.02 m	1.30 m	700 MHz: 1.38 m 400 MHz: 1.30 m	700 MHz: 1.83 m 400 MHz: 1.75 m
CTIA-compliant	No (R&D)	No (R&D)	Yes	Yes	Yes

Service you can rely on



Onsite calibration
Onsite support and repair
Bridging Devices



Remote Support
ELEKTRA Software Update



Training
Project Management
and much more....



ROHDE & SCHWARZ
Make ideas real



SERVICE LEVEL AGREEMENTS FOR ROHDE & SCHWARZ EMC SYSTEMS



Resources & Training

Webpages

[Medical device testing | Rohde & Schwarz \(rohde-schwarz.com\)](https://www.rohde-schwarz.com)

[EMC test solutions | Rohde & Schwarz \(rohde-schwarz.com\)](https://www.rohde-schwarz.com)

[Automotive EMC testing | Rohde & Schwarz \(rohde-schwarz.com\)](https://www.rohde-schwarz.com)

[Aerospace and military EMC testing | Rohde & Schwarz \(rohde-schwarz.com\)](https://www.rohde-schwarz.com)

Newsletters

[CISPR Newsletter | Rohde & Schwarz \(rohde-schwarz.com\)](https://www.rohde-schwarz.com)

Knowledge Center & Technology Academy

[R&S@ELEKTRA | Mediacenter | Rohde & Schwarz \(rohde-schwarz.com\)](https://www.rohde-schwarz.com)

<https://www.rohde-schwarz.com/cloud/store/DE/en/EUR/c/training>

Webinars & Educational Events

[Everything Test | On Demand Webinar Series | Rohde & Schwarz \(rohde-schwarz.com\)](https://www.rohde-schwarz.com)

[DEMC 2024 | Global tour | Rohde & Schwarz \(rohde-schwarz.com\)](https://www.rohde-schwarz.com)



Intro to EMC Testing

Our technical experts focus on the basics of pre- and full-compliance Electromagnetic Compatibility (EMC) testing, and introduces the latest technologies used to perform EMC testing for requirements set by a standardization body such as CISPR, ETSI, or the FCC.



Webinar: Latest developments in CISPR Automotive EMI standards

This webinar addresses the applicability of FFT-based receivers for EMI compliance measurements against international standards, gives an inside view on the technology of such receivers and will conclude with practical use cases.



Rohde & Schwarz is your EMC test partner

Rohde & Schwarz is your EMC supplier for

Test equipment

Test systems

Test software

Upgrades

Turnkey solutions

Service and calibration

Rohde & Schwarz can guide you through the
process of creating the right EMC solution to
fit your needs today and tomorrow!



THANK YOU!