PRESENTED BY

INTERFERENCE TECHNOLOGY®

2021 EMC TESTING GUIDE

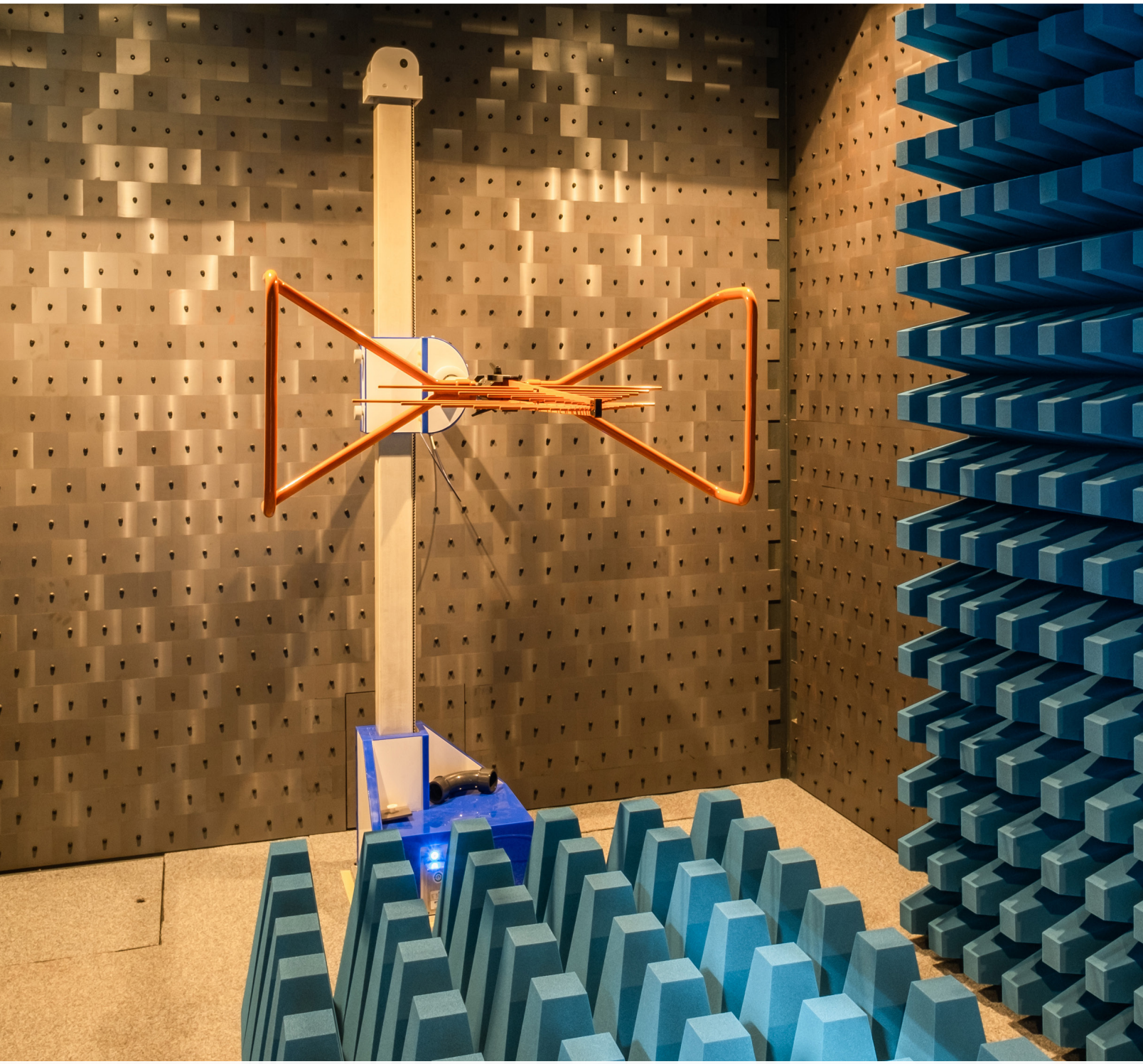
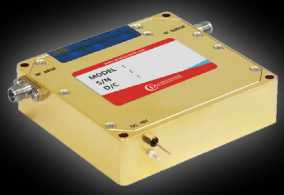
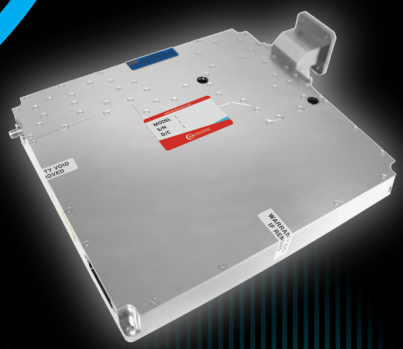


TABLE OF CONTENTS

EXODUS ADVANCED COMMUNICATIONS

YOUR POWERFUL SOURCE FOR EMC SOLUTIONS





10kHz-51GHz Amps
LNA's, CW, PULSE
Low to High Power

3674 E. SUNSET RD. STE 100
LAS VEGAS, NV 89120
TEL: 702-534-6564

www.exoduscomm.com

sales@exoduscomm.com

EMC EQUIPMENT MANUFACTURERS SUPPLIER MATRIX

Introduction

The following chart is a quick reference guide of test equipment and includes everything you'll need from the bare minimum required for key evaluation testing, probing, and troubleshooting, to setting up a full in-house precompliance or full compliance test lab. The list includes amplifiers, antennas, current probes, ESD simulators, LISNs, near field probes, RF signal generators, spectrum analyzers, EMI receivers, and TEM cells. Equipment rental companies are also listed. The products listed can help you evaluate radiated and conducted emissions, radiated and conducted immunity, and a host of other immunity tests, such as ESD and EFT.

EMC Equipment Manufacturers Supplier Matrix		Type of Product/Service												
Manufacturer	Contact Information - URL	Antennas	Amplifiers	Near Field Probes	Current Probes	Spectrum Analyzers/EMI Receivers	ESD Simulators	LISNs	Radiated Immunity	Conducted Immunity	Pre-Compliance Test	TEM Cells	Rental Companies	RF Signal Generators
A.H. Systems	www.ahsystems.com	X	X		X						X			
Aaronia AG	www.aaronia.com	X	X			X					X			
Advanced Test Equipment Rentals	www.atecorp.com/category/emc-compliance-esd-rfi-emi.aspx	X	X			X	X	X	X	X	X		X	X
AR RF/Microwave Instrumentation	www.arworld.us	X	X			X		X	X	X	X			X
Anritsu	www.anritsu.com					X					X			X
BHD Test and Measurement	www.bhdtm.com		X			X	X	X	X	X	X		X	X
Compliance Worldwide	www.complianceworldwide.com								X	X	X			
CPI	www.cpii.com	X	X			X								
Electro Rent	www.electrorent.com		X			X	X	X	X	X	X		X	X
EM Test	www.emtest.com/home.php									X	X	X		
EMC Partner	www.emc-partner.com						X			X				
Empower RF Systems	www.empowerrf.com		X						X					
Exodus Advanced Communications	www.exoduscomm.com		X											
F2 Laboratories	www.f2labs.com								X	X	X			
Gauss Instruments	www.gauss-instruments.com/en/					X								
Haefley-Hippotronics	www.haefely-hipotronics.com						X			X				
Instruments For Industry (IFI)	www.ifi.com		X						X	X				

EMC Equipment Manufacturers Supplier Matrix		Type of Product/Service												
Manufacturer	Contact Information - URL	Antennas	Amplifiers	Near Field Probes	Current Probes	Spectrum Analyzers/EMI Receivers	ESD Simulators	LISNs	Radiated Immunity	Conducted Immunity	Pre-Compliance Test	TEM Cells	Rental Companies	RF Signal Generators
ITG Technologies, Inc.	www.itg-electronics.com		X											
Kent Electronics	www.wa5vjb.com	X												
Keysight Technologies	www.keysight.com/main/home.jspx?cc=US&lc=eng			X		X		X			X			X
Microlease	www.microlease.com/us/home		X			X	X	X	X	X	X		X	X
Milmega	www.milmega.co.uk		X						X	X				
Narda/PMM	www.narda-sts.it/	X	X			X		X	X	X	X			
Noiseken	www.noiseken.com						X			X	X			
Ophir RF	www.ophirrf.com		X							X				
Pearson Electronics	www.pearsonelectronics.com				X									
PPM Test	www.ppmtest.com	X			X						X			
Rigol Technologies	www.rigolna.com			X	X	X					X			X
Rohde & Schwarz	www.rohde-schwarz.com/us/home_48230.html	X	X	X	X	X		X	X	X	X			X
Siglent Technologies	www.siglentamerica.com			X		X					X			X
Signal Hound	www.signalhound.com			X		X					X			X
Solar Electronics	www.solar-emc.com	X			X		X	X		X				
TekBox Technologies	www.tekbox.com		X	X				X			X	X		
Tektronix	www.tek.com			X		X					X			
Teseq	www.teseq.com/en/index.php		X		X		X		X	X	X	X		
Test Equity	www.testequity.com/leasing/		X			X	X	X	X	X	X		X	X
Thermo Keytek	www.thermofisher.com/us/en/home.html						X			X				
Thurlby Thandar (AIM-TTi)	www.aimtti.us					X					X			X
Toyotech (Toyo)	www.toyotechus.com/emc-electromagnetic-compatibility/	X	X			X		X	X		X			
TPI	www.rf-consultant.com													X
Transient Specialists	www.transientspecialists.com								X	X		X		
TRSRenTelCo	www.trs-rentelco.com/SubCategory/EMC_Test_Equipment.aspx	X	X			X		X	X	X	X		X	X
Vectawave Technology	www.vectawave.com		X											
Windfreak Technologies	www.windfreaktech.com													X

Keep it simple!
Sense with MEMS.

WÜRTH ELEKTRONIK

© elSmart

WE are here for you!

Join our free webinars on
www.we-online.com/webinars

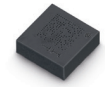
MEMS Sensor Portfolio & Customer Service

Sensors are an integral part of every future application. Measuring temperature, humidity, pressure or acceleration has never been easier. Take advantage of services like our Software Development Kit and Evaluation Boards available off-the-shelf. Detailed documentations as well as the direct support by trained engineers will leave no questions open.

With excellent measuring accuracy and long-term stability, the sensors provide high precision and accurate output values with intelligent on-chip interrupt functions.

Combine sensors and wireless connectivity – start your IoT application today:
www.we-online.com/sensors

- Support by engineers within 24 h
- Excellent measuring accuracy
- Factory calibrated & ready to use
- On-chip interrupt functions
- Implemented algorithms
- SPI & I²C digital interfaces



3 Axis Acceleration
WSEN-ITDS

Temperature Sensor IC
WSEN-TIDS

Absolute Pressure
WSEN-PADS

Differential Pressure
WSEN-PDUS

Humidity
WSEN-HIDS

#SensewithMEMS

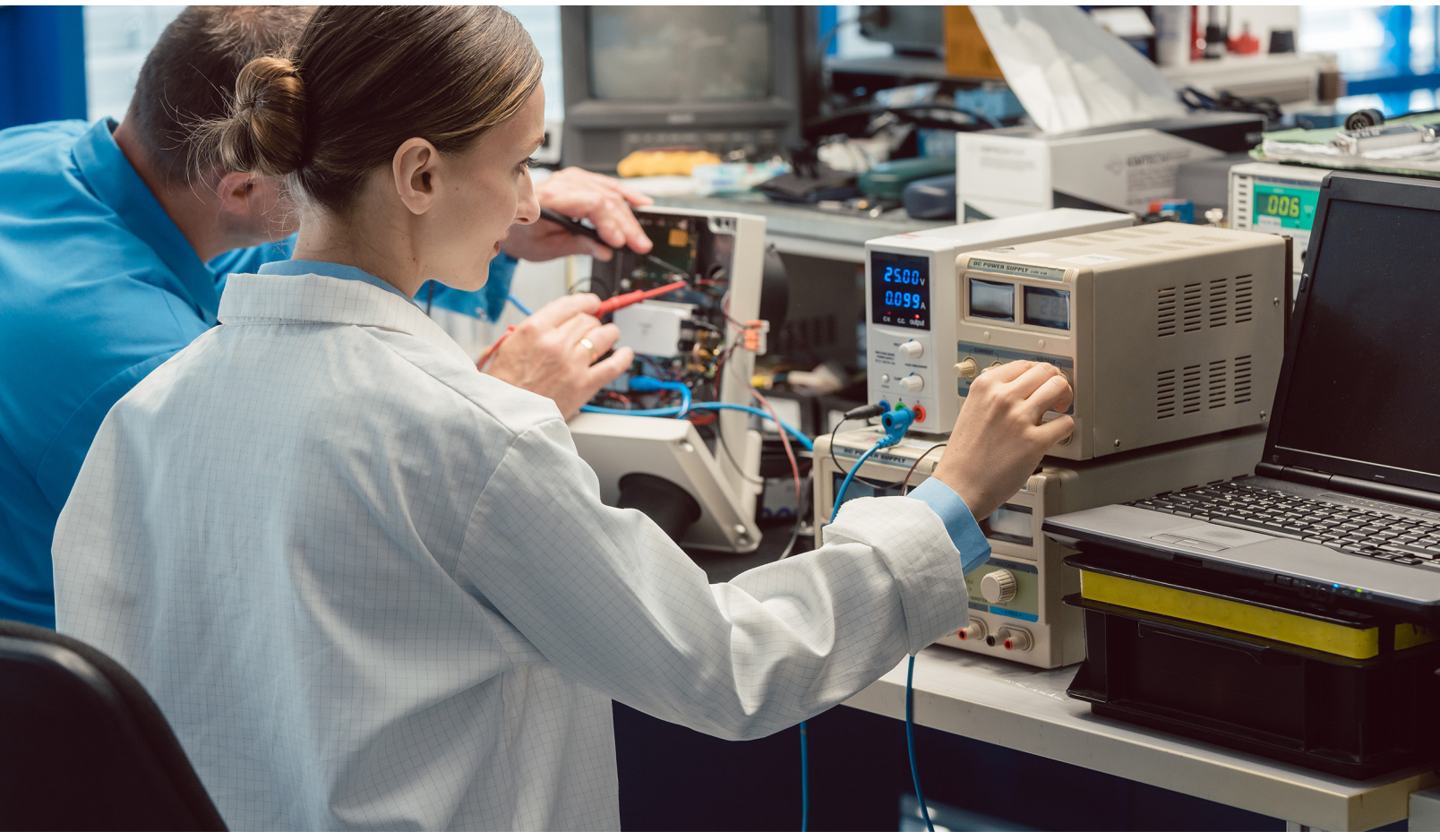
HOW TO PREPARE YOUR PRODUCT AND YOURSELF FOR EMC TESTING

Ghery Pettit
Pettit EMC Consulting
Ghery@PettitEMCConsulting.com

Introduction

Your product has EMC requirements. You have to test it to demonstrate compliance with those requirements. How do you prepare for the test? How do you prepare your product for the test?

These are two different areas that need preparation before you go to the lab. Let's look at them, one at a time.



HOW TO PREPARE YOUR PRODUCT AND YOURSELF FOR EMC TESTING

How do you prepare for the test?

- First, you need to understand what you need to gather before going to the lab. A step before that is that you must select a lab to perform the tests. Then, you need to know what information the lab will need prior to the tests in order to allow them to properly test your product and write a test report. Some labs may require a written test plan before performing the tests, and the contents of the test plan will aid them by gathering information needed for the test reports.

How do you select a lab? First, you need to know what will be required of the laboratory in order for its results to be acceptable in the countries in which you wish to sell your product. Not all labs are acceptable everywhere in the world. The requirements for a lab to be accepted in various parts of the world is beyond the scope of this article, but you should ensure that the lab's results and reports will be acceptable. Some parts of the world have no restrictions on what lab you may use, others may require that the lab be accredited for testing in their country. When in doubt, ask to see proof.

Secondly, mere possession of accreditation is not, in and of itself, evidence that the lab truly does quality work. You should become educated on the requirements around the world and perform your own inspections of the candidate laboratories. Some labs will welcome your visit, others might not. You will have to decide what level of comfort is adequate for your company. If you don't have the expertise in-house you might consider hiring a consultant to evaluate the laboratory or laboratories you are considering.

Once you have settled on a laboratory to perform the tests, find out from the lab what information they need you to provide. Later we'll talk about the information that a laboratory must include in the test report, and you will see that much of it comes from you. Know what information is needed and have it available when you go to the lab. Part of you laboratory selection process should include asking about lead time requirements. Are they so busy that they can't fit in the number of days you will need for the tests until 6 months from now? And you need to ship in 1 month? That is important information. Few things upset management more than being told that they can't start shipping product (and receiving money) until a few months after they had planned. Your fault or not, you will be blamed, so make sure you understand your company's schedule requirements and what the laboratory can deliver.

Also, talk to the lab and have a good idea how long the tests will take and then when they can deliver a test report for your review. Talk to your marketing people to see when they plan on announcing this product and start shipping it. You don't want to be the bottleneck that stops the process. Have these discussions early (both with the lab and with your own people) and keep the information up to date. Ensure that you keep your management informed of the status and any delays that you see coming.

How do you prepare the product for the test?

First, design the product with EMC in mind. Provide guidance to the development team early and often on design features that they should include to increase their chances of passing the first time. Review the designs to make sure that obvious mistakes are not included in the product design. Perform preliminary development tests when possible to catch mistakes and failures early, when they can more easily be fixed.

Once the product is designed and debugged, make sure that all necessary hardware and software is available for the test. The hardware that you will need to provide to the laboratory may be more than just the box you are testing. What about peripheral devices? Are they common items that the laboratory might already have in their possession? Or are they special items that only you might have? You might also ensure that all subassemblies are installed correctly and that all chassis and enclosure fasteners are tight. What about the cables connecting the various parts of the system? Are specially designed cables necessary?

A classic example to consider is if your product includes an HDMI interface. If your product depends on properly shielded cables, with the shields properly terminated, cables that simply meet the HDMI cable specification may not be adequate. The HDMI specification does not address the termination of the outer shield of the cable and many HDMI compliant cables do not have this outer shield terminated or terminated properly. They meet the HDMI specification, but are not typically adequate from an EMC perspective. Does your product need the shield terminated? Make sure the cables used for the test (and sold with your product) have the shields terminated correctly.

If any software is required in order for your product to be exercised as required by the EMC standard to which it is being tested make sure you pack that software with the product, or pre-install it and test it to make sure it works. Remember that the clock is running when you arrive at the lab and you don't want to be paying their hourly rate to troubleshoot you product to make it work, or waste time running back to your company to get software you forgot.

Also, it's wise to bring the following items: product documentation, installation manual, user manual, extra tools – especially specialized ones required to remove covers or cables, etc., backup copies of software, a backup laptop, backup hardware in case of product failure (especially important for potentially destructive tests like ESD), extra cables, troubleshooting items like ferrite chokes, copper tape, and aluminum foil.

What information might you need to provide to the lab? The laboratory is going to write a test report (or reports) for you at the completion of the tests (assuming the product passed, writing a full report for a product that fails is a waste of time and your money). ISO/IEC Guide 17025:2005 provides a list of items that must be included in the test report and regulatory agencies add their own requirements. Let's look at the items that ISO/IEC 17025 requires:

Articles 5.10.2 and 5.10.3 of ISO/IEC 17025 list a number of required items to be included. These are;

- 5.10.2a – The report is labeled with a title, such as "Test Report"
- 5.10.2b – The name and address of the laboratory used for the measurement
- 5.10.2c – Unique identifier of the report on each page and a clear identification of the end of the report
- 5.10.2d – Name and address of the client
- 5.10.2e – Test methods clearly identified
- 5.10.2f –
    - Description of the condition of the EUT
    - Clear and unambiguous identification of the EUT on the cover or first page of the report. All applicable model numbers and manufacturer's trade names are to be listed here
- 5.10.2g – Date(s) of the test shall be identified
- 5.10.2h – reference to the sampling plan and procedures used by the lab (not typically needed in an EMC test report)
- 5.10.2i – test results with units of measurement
- 5.10.2j – name(s), function(s) and signature(s) of person(s) authorizing the test report
- 5.10.2k – a statement to the effect that the results relate only to the items tested
- 5.10.2 Note 1 – hard copies of test reports should include the page number and total number of pages
- 5.10.2 Note 2 – a statement that the test report shall not be reproduced except in full, without written approval of the lab.
- 5.10.3.1a – deviations from, additions to, or exclusions from the test methods, and information on specific test conditions, such as environmental conditions
    - Temperature, humidity, barometric pressure
    - Operating voltage and frequency
- 5.10.3.1b – a statement of compliance/non-compliance with requirements and/or specifications
- 5.10.3.1c – a statement on the estimated uncertainty of measurement
- 5.10.3.1d – where appropriate and needed, opinions and interpretations
- 5.10.3.1e – additional information which may be required by specific methods, customers or groups of customers

In the United States, the Federal Communications Commission (FCC) has some additional requirements. These will vary depending on the type of approval process used for the product.

Devices authorized under Verification

- 47 CFR 2.955(a)(3)
    i. Indicate the actual date all testing was performed (see also 17025 5.10.2g)
    ii. State the name of the test laboratory, company, or individual performing the verification testing. (see also 17025 5.10.2b)
    iii. Contain a description of how the device was actually tested, identifying the measurement procedure and test equipment that was used (see also 17025 5.10.2e)
    iv. Contain a description of the equipment under test (EUT) and support equipment connected to, or installed within, the EUT (see also 17025 5.10.2f)
    v. Identify the EUT and support equipment by trade name and model number and, if appropriate, by FCC Identifier and serial number
    vi. Indicate the types and lengths of connecting cables used and how they were arranged or moved during testing
    vii. Contain at least two drawings or photographs showing the test set-up for the highest line conducted emission and showing the test set-up for the highest radiated emission. These drawings or photographs must show enough detail to confirm other information contained in the test report. Any photographs used must be focused originals without glare or dark spots and must clearly show the test configuration used
    viii. List all modifications, if any, made to the EUT by the testing company or individual to achieve compliance with the regulations in this chapter
    ix. Include all of the data required to show compliance with the appropriate regulations in this chapter (see also 17025 5.10.2i)
    x. Contain, on the test report, the signature of the individual responsible for testing the product along with the name and signature of an official of the responsible party, as designated in §2.909

Devices authorized under Certification

- 47 CFR 2.1033(b)

1. The full name and mailing address of the manufacturer of the device and the applicant for certification (see also 17025 5.10.2d)
2. FCC identifier
3. A copy of the installation and operating instructions to be furnished the user. A draft copy of the instructions may be submitted if the actual document is not available. The actual document shall be furnished to the FCC when it becomes available
4. A brief description of the circuit functions of the de-

vice along with a statement describing how the device operates. This statement should contain a description of the ground system and antenna, if any, used with the device

5. A block diagram showing the frequency of all oscillators in the device. The signal path and frequency shall be indicated at each block. The tuning range(s) and intermediate frequency(ies) shall be indicated at each block. A schematic diagram is also required for intentional radiators
6. A report of measurements showing compliance with the pertinent FCC technical requirements. This report shall identify the test procedure used (e.g., specify the FCC test procedure, or industry test procedure that was used), the date the measurements were made, the location where the measurements were made, and the device that was tested (model and serial number, if available). The report shall include sample calculations showing how the measurement results were converted for comparison with the technical requirements
7. A sufficient number of photographs to clearly show the exterior appearance, the construction, the component placement on the chassis, and the chassis assembly. The exterior views shall show the overall appearance, the antenna used with the device (if any), the controls available to the user, and the required identification label in sufficient detail so that the name and FCC identifier can be read. In lieu of a photograph of the label, a sample label (or facsimile thereof) may be submitted together with a sketch showing where this label will be placed on the equipment. Photographs shall be of size A4 (21 cm x 29.7 cm) or 8 x 10 inches (20.3 cm x 25.4 cm). Smaller photographs may be submitted provided they are sharp and clear, show the necessary detail, and are mounted on A4 (21 cm x 29.7 cm) or 8.5 x 11 inch (21.6 cm x 27.9 cm) paper. A sample label or facsimile together with the sketch showing the placement of this label shall be on the same size paper
8. If the equipment for which certification is being sought must be tested with peripheral or accessory devices connected or installed, a brief description of those peripherals or accessories. The peripheral or accessory devices shall be unmodified, commercially available equipment

Devices authorized under Declaration of Conformity

- 47 CFR 2.1075(a)(3)

i. The actual date or dates testing was performed
ii. The name of the test laboratory, company, or individual performing the testing. The Commission may request additional information regarding the test site, the test equipment or the qualifications of the company or individual performing the tests
iii. A description of how the device was actually tested, identifying the measurement procedure and test equipment that was used
iv. A description of the equipment under test (EUT) and support equipment connected to, or installed within, the EUT
v. The identification of the EUT and support equipment by trade name and model number and, if appropriate, by FCC Identifier and serial number
vi. The types and lengths of connecting cables used and how they were arranged or moved during testing
vii. At least two photographs showing the test set-up for the highest line conducted emission and showing the test set-up for the highest radiated emission. These photographs must be focused originals which show enough detail to confirm other information contained in the test report
viii. A description of any modifications made to the EUT by the testing company or individual to achieve compliance with the regulations
ix. All of the data required to show compliance with the appropriate regulations
x. The signature of the individual responsible for testing the product along with the name and signature of an official of the responsible party, as designated in §2.909
xi. A copy of the compliance information, as described in §2.1077, required to be provided with the equipment

In Taiwan, the Bureau of Standards, Metrology and Inspection (BSMI) has a few of their own requirements for report content.

- If testing with different numbers of cables connected to multiple samples of a given I/O port type is performed, data for each number of cables used shall be provided to show that the addition of the final cable did not increase emissions by more than 2 dB.
- A statement that the final test results represent the worst case, along with a listing of the configuration variations that were investigated to determine the worst case.
- Clear photographs of the test setup providing sufficient detail to duplicate the test results. Each test setup must be documented.
    - 6 exterior pictures of a system EUT for class A equipment
    - 6 exterior and 6 interior pictures of a system EUT for class B equipment.
    - Pictures required for the power supply and internal boards. Board photos required of both sides with sufficient detail to identify EMC critical parts.
    - Minimum photo size is 4 by 6 inches
- List of removable EMI suppression components in the product.
- List of key EMI generation components (clock generators and distribution parts)

- Block diagram of the EUT showing the clock distribution
- BSMI cover sheet containing the following information:
  - Product Name. This shall be the same name as provided on shipping and final sales packaging
  - Applicant (Intel for our products)
  - Description of nameplate mains characteristics
  - Logo or Brand
  - Model Number or Type. Detailed model number(s)
  - Test Result. Passed. State class A or class B
  - Original Signature. Electronic signatures are acceptable if the report and all supporting documentation is submitted on a CD-ROM

The following items may be specific to one regulator, but should be provided in the report:

- List of accreditations, approvals, listings, etc held by the laboratory. Include identification numbers if applicable.
- If multiple model numbers are covered by the report, provide a description and evidence of differences reviewed by the laboratory.
- Name and signature of the person taking the data. Needed for each set of data in the report.
- List all test equipment used during the tests.
  - Test equipment type
  - Manufacturer
  - Model number
  - Serial number
  - Calibration date and calibration due date
- Details of applicable regulatory compliance labels showing label details and location on the product.
- List of all components of the EUT system. Include internal components such as power supplies, motherboards, hard disk drives, floppy disk drives, CD-ROM drives and add-in cards.
  - Equipment type
  - Manufacturer
  - Model number
  - Serial number
- List of all cables
  - Length
  - Type (shielded, unshielded, coax, etc)
  - Devices interconnected with the cable
- EUT exercise/stimulation software used
- Any required user warning statements.

As you can see, preparation for testing a product to EMC requirements is an intensive process. You will need to go through this list of information and make sure that any of it that must be provided to the laboratory is identified and provided in a format that is useful to the laboratory.

Talk to them in advance and make sure that you have everything they need, in a format that they can use. The time (and money) that you save is your own (or your employers).

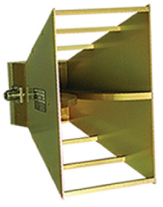
Does your antenna supplier do *all* this?

	Your Supplier	A.H. Systems
Design / build their own?		✔
99% in stock now?		✔
Next day, on-time delivery?		✔
Over a hundred items to choose from?		✔
Portable antenna kits?		✔
Equipment still working after 40 years?		✔
Over 80 years of experience?		✔
Personal technical support?		✔
Personal Customer Service?		✔
Global support network?		✔

A.H. Systems does ***all*** of this, ***all*** of the time because we are the EMI test Antenna Specialists. We do not build "Boxes". We do not build "Systems". We do design and build the highest quality, most accurate EMI test antennas (20 Hz - 40 GHz).

It may be more convenient to buy everything from one supplier, but remember "Your test system is only as good as the antenna you put in front of it!"

Log Periodics
80 MHz - 7 GHz
13 Models



DRG Horns
170 MHz - 40 GHz
6 Models

All in one small package
20 Hz - 40 GHz

Biconicals
20 MHz - 18 GHz
7 Models

The Antenna Specialists

Innovation Quality Performance

Phone: (818)998-0223 ♦ Fax (818)998-6892
http://www.AHSystems.com

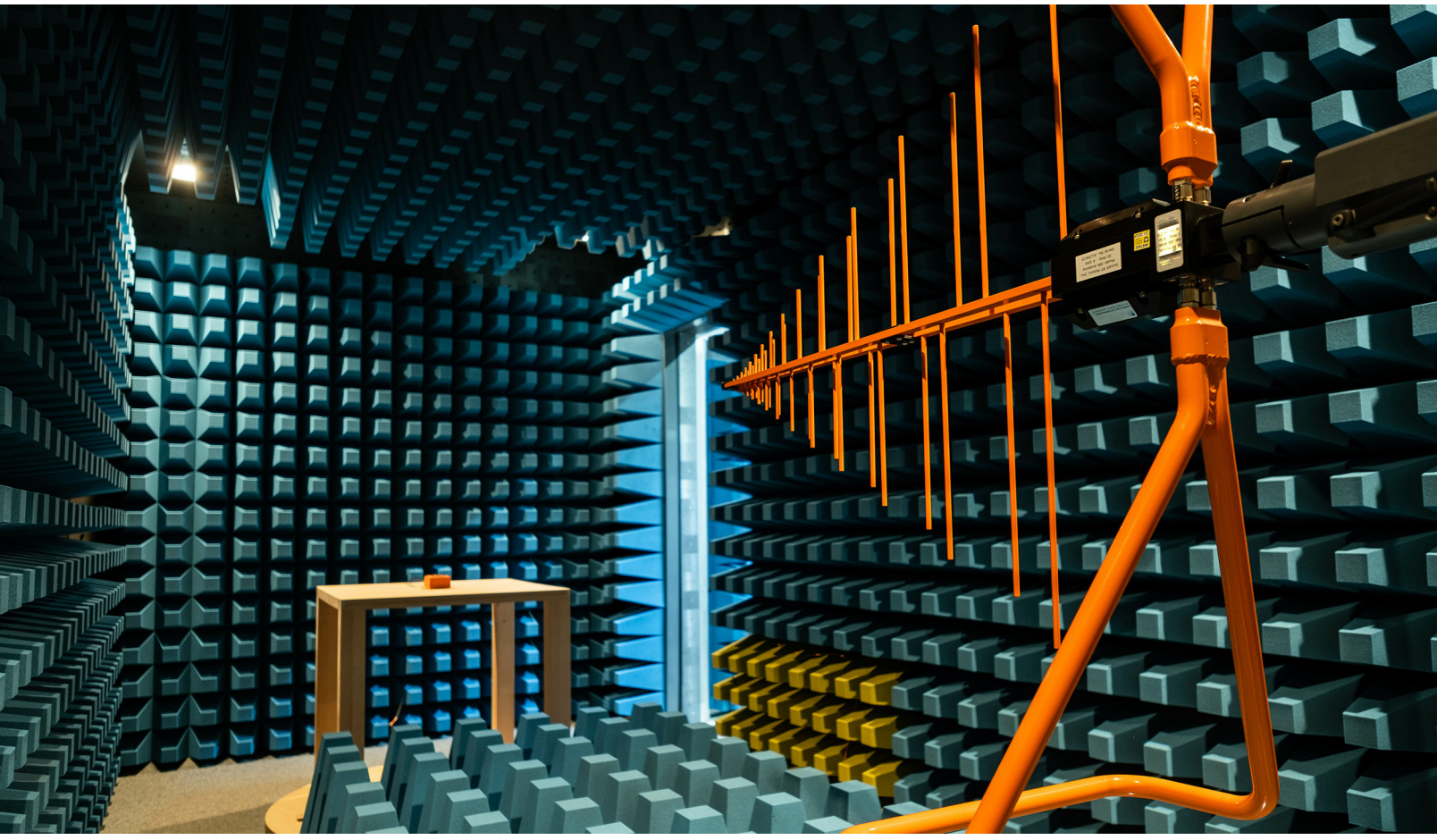
A.H. Systems

SUMMARY OF COMMERCIAL EMC TESTS

Ghery Pettit
Pettit EMC Consulting
Ghery@PettitEMCConsulting.com

Introduction

Commercial EMC tests cover a wide range of products. These include the obvious ones like computers and their peripherals, but also cover household appliances, electric tools and a wide variety of other products. While the standards, including limits and test methods may differ, all EMC test standards have a few things in common. The most basic are the limits for emissions and the types and levels of immunity testing.



SUMMARY OF COMMERCIAL EMC TESTS

Emissions tests (and their associated limits) are put in place for commercial equipment primarily to protect radio and television broadcasting services. Other radio communications services are also protected. While a very few commercial emissions standards existed prior to the introduction of the personal computer to the marketplace, the proliferation of these devices spurred the development of standards and regulations around the world due to the large number of interference complaints directly traceable to these new devices. Early personal computing devices were designed and built with no regard to controlling radio frequency emissions and, as a result, they generated large amounts of RF emissions. Indeed, it could be argued that the early personal computing devices were broadband radio transmitters masquerading as computers. Mainframe computers had similar weaknesses, but as they typically weren't installed in residential areas the impact was smaller.

Emissions testing typically comprises of two parts. Conducted emissions on power and telecommunications ports and radiated emissions. The breakpoint between the two (conducted and radiated) in commercial standards is 30 MHz. This frequency was chosen as at the typical test distances involved (3 meters and 10 meters today) frequencies above 30 MHz tend to provide plane wave (far field) emissions, allowing for fairly repeatable measurements from laboratory to laboratory. Below 30 MHz this may not be the case. Thus, conducted emissions are measured. Limits for powerline conducted emissions were set based on the source and victim devices being connected to the same circuit. Limits for conducted emissions on telecommunication ports are set assuming a certain conversion of the differential mode (desired) signals on the cable being converted to common mode (due to characteristics of the cable) which then radiates.

Conducted Emissions

Conducted emissions on the incoming power lines are measured (typically) using a Line Impedance Stabilization Network (LISN) or Artificial Mains Network (AMN). These are two different names for the same box. The LISN or AMN is placed between the Equipment Under Test (EUT) and the incoming power line (mains) to provide a defined power line impedance and a coupling point to the receiver (*Figure 1*). The LISN or AMN is placed on the horizontal ground plane, or directly beneath it with the EUT connected directly to the EUT port. The block diagram below shows this test setup.

The EUT is placed either on the horizontal ground plane on the floor (with an insulating spacer) or on an 80 cm high non-conducting table, depending on the intended installation of the EUT (table top or ground mounted). The frequency range of interest is scanned with the appropriate detectors and bandwidth and the results are noted. Measurement are made on each conductor of the incoming line separately. Most commercial EMC standards have measurements made over the frequency range of 150 kHz to 30 MHz.

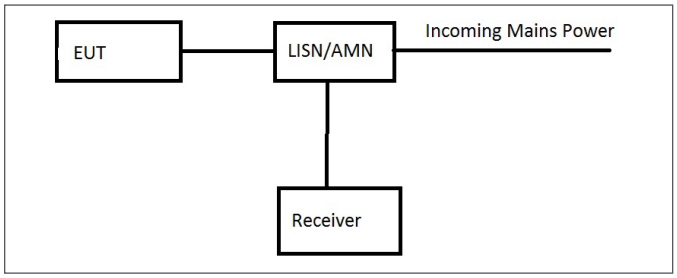


Figure 1 – Generalized test setup for conducted emissions using a line impedance stabilization network (LISN).

Radiated Emissions

Radiated emissions may be measured in either an Open Area Test Site (OATS) or an RF Semi-Anechoic Chamber (SAC). The OATS is the "gold standard" test facility. It consists of a large open area free of objects which might reflect RF energy. It typically is equipped with a reflecting ground plane. The size of the clear area is defined in various standards as an elliptical area whose major axis is twice the measurement distance and whose minor axis is the square root of 3 times the measurement distance. Experience has shown over the decades that these dimensions are too small. Doubling them has been tried and even that has been shown to have its weaknesses, especially when the OATS is surrounded by a chain link fence for security. The picture below shows a 30 meter OATS built in 1989 for Tandem Computers Incorporated near Hollister, California. The clear area is at least twice the required dimensions for a 30 meter site and takes a considerable amount of land. This site is no longer in operation, but it illustrates the point. The building on the ground plane was constructed of RF transparent material and covered the turntable. All utilities were run underground, including the air conditioning ducts with the air conditioning units being installed outside the clear area. The site was never utilized at a measurement distance of 30 meters, so it was a superb 10 meter site.

Figure 2 – A typical open area test site (OATS).

A significant weakness of the OATS facility is that in addition to measuring the emissions from the EUT it is a great facility to measure all the local RF ambient signals from broadcast and communications services, as well. If these signals are strong enough they will totally mask the emissions from the EUT that you were trying to measure. As a result, for best operation an OATS must be located in a very remote area. And this is no guarantee that the ambient level will remain low. Apple Computer had a great OATS near Pescadero, California that had a very low ambient when it was built in the 1980s. Apple ultimately stopped using the facility when the local ambient signals grew to the point where operation was no longer possible and moved totally to 10 meter SACs near their development facilities.

Regardless of whether measurement are taken at an OATS or in a SAC, the block diagram of the test set-up remains the same. Emissions from the EUT are measured using an antenna for the appropriate frequency range, a pre-amplifier (if necessary) and a measuring receiver. Measurements are taken with the antenna in both the vertical and horizontal polarities. See the block diagram in *Figure 3*.

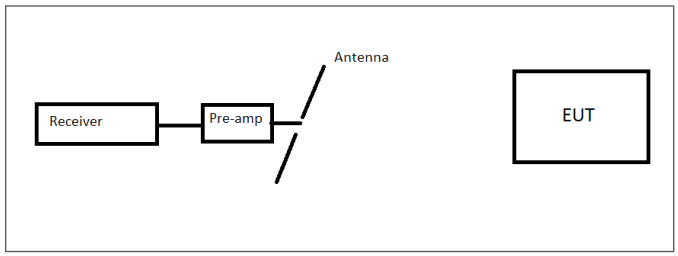


Figure 3 – General test setup for radiated emissions testing.

The need for height scans is shown by the diagram in *Figure 4*. The objective is to adjust the antenna height until the direct and reflected signals are maximized. An example of an antenna mast for this purpose is shown in the photograph above of the Tandem 30 meter OATS (*Figure 2*).

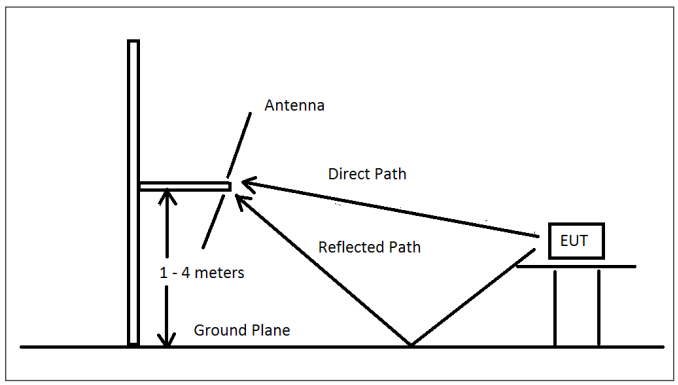


Figure 4 – Diagram showing the direct and reflected waves. The antenna height is adjusted to maximize the measurement.

Emissions tests are required in many countries around the world. Immunity testing of commercial products is required in a smaller number of countries, but these are some major countries, so a manufacturer must be aware of them.

Commercial Immunity Tests
Commercial immunity testing typically covers the following types of tests:

1. Electrostatic Discharge (ESD)
There are two types of ESD tests – contact discharge and air discharge. In the contact discharge test the tip of the ESD simulator is placed on the test point of the EUT and the discharge is initiated. The discharge occurs inside the simulator and these tests are fairly repeatable. In the air discharge test the simulator is charged to the specified voltage and brought into contact with the EUT. The discharge, if it occurs, happens before contact is made jumping the air gap between the tip of the simulator and the EUT. How large this gap is depends of the atmospheric pressure, temperature, angle of approach, and relative humidity. It can also depend on how fast the operator approaches the EUT with the ESD gun Air discharge testing is not as repeatable, but it simulates a different ESD event. Both types of tests are typically required. For computer equipment CISPR 24 requires a contact discharge test at 4 kV and air discharge tests up to 8 kV. Tests are typically performed using the equipment and procedures called out in IEC 61000-4-2. The EUT is allowed to react to the test, but it must self-recover after the test. A classic example is a computer playing music over a speaker. You hear a POP! in the speaker when the ESD event occurs, but the music keeps playing afterwards. This is considered a pass. If the music stopped and required operator intervention to re-start, that would be considered a failure.

2. Radiated electric field immunity
This tests the immunity of the EUT to nearby radio transmitters. The frequency range of 80 MHz to 1 GHz is typically tested, although newer standards have tests required as high as 6 GHz. This test is performed in a fully anechoic chamber or a SAC with removable absorbers placed on the floor. Signal levels are used that would annoy the neighbors and cause the local regulators to issue fines, so a shielded environment is a necessity. The current requirements in IEC 61000-4-3 (a commonly used basic standard) call for the E-field to be uniform to within certain requirements before the EUT is brought into the test volume. Four sides of the EUT are typically evaluated. The EUT typically must continue to operate through the test as though nothing was happening to it or must self-recover with no loss of data to be considered a pass.

3. Electrical Fast Transients
This test introduces a series of rapid pulses into the EUT through the power and any signal lines that could exceed 3 meters in length. Like ESD testing, the EUT must operate after the test without operator intervention, but

may react to the test as it occurs, so long as the system self-recovers with no loss of data. IEC 61000-4-4 calls out the test equipment and procedures for this test.

4. Electric Surge
This test simulates what happens on the power input to the EUT when there is a nearby lightning strike. High energy surges are applied to the EUT line input. IEC 61000-4-5 details the test equipment and procedures for performing surge testing.

5. Conducted RF
In commercial standards the breakpoint between conducted RF and radiated RF immunity testing is typically 80 MHz. Generating uniform fields much below 80 MHz is difficult. As a result, below that frequency RF energy is typically injected onto cables connected to the EUT. An example of a block diagram for such a test is shown in *Figure 5*. The 6 dB attenuator is placed as close to the Coupling Decoupling Network (CDN) as possible. While this isn't clearly shown in IEC 61000-4-6, the reason for placing it as close to the CDN as possible is that it provides a matching impedance to the transmission line, maximizing power transfer to the CDN, whose input impedance is not precisely known. Otherwise, you may be throwing away half the power you paid to generate.

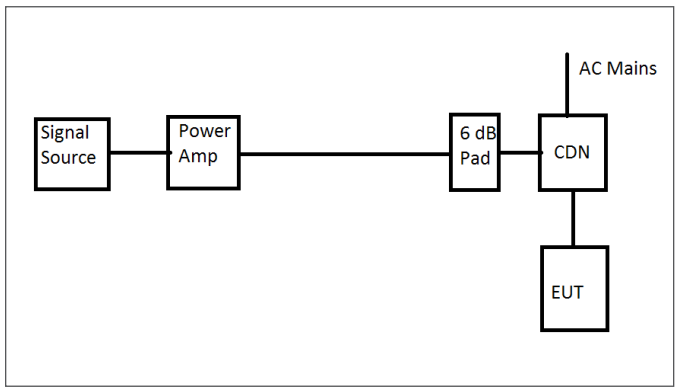


Figure 5 – Typical test setup for the conducted immunity test.

The typical frequency range for conducted RF immunity testing of commercial equipment is 150 kHz to 80 MHz.

6. Power Frequency Magnetic Fields
This test is run for products which might reasonably be expected to have immunity problems with power frequency magnetic fields. Such products, as called out in CISPR 24 for example, might include Cathode Ray Tube (CRT) displays, magnetic field sensors and Hall devices. The EUT is placed in the middle of a large coil of wire through which a power frequency current flows. The current level to generate the specified field level (for example, 1 Amp/meter in CISPR 24) is run through the coil and the EUT is checked for proper operation. All three axes are tested. Most products do not require this test, but it is included in the product family standards. IEC 62000-4-8 details how to perform this test.

7. Dips and dropouts
This test is designed to simulate real world examples of momentary input power voltage fluctuations. In the case of CISPR 24 (and CISPR 35) there are three tests that are performed, typically by a computerized power source. The first is a >95% voltage reduction for one half cycle of the incoming power. The voltage change occurs at the zero crossover point on the power waveform. This simply means that one half cycle of the incoming power to the EUT is chopped off. The EUT is allowed to react, but must self-recover without operator intervention. The second test is a 30% reduction (70% residual voltage) for one half second (25 cycles at 50 Hz or 30 cycles at 60 Hz) - a short brown-out. Again, the EUT may react, but must self-recover. The third commonly used test is a >95% reduction in input voltage for 5 seconds. It's like the power cord was pulled out of the wall socket for 5 seconds and then plugged back in. Obviously, unless the EUT has a built in battery or UPS, it will crash. As long as function can be restored by the operator in accordance with the instructions and no data protected by battery back-up is lost or damaged, the EUT passes this test. IEC 61000-4-11 provides the details on how these tests are to be run.

The test levels utilized in commercial immunity tests are designed to provide a reasonable level of certainty that the product will operate in its intended environment. They do not represent the worst case that a product might experience in the field, but they have been shown over the years to be adequate. Indeed, most products exhibit higher levels of immunity that required when tested to their breaking point and the design features used to meet the emissions requirements typically are adequate for providing this level of immunity.

THE VSG60A + THE BB60C

Generate RF. Analyze RF. Streaming in real-time up to 6 GHz.

Grab your laptop and these powerful, portable RF test devices for signal analysis on the go – ALL POWERED OVER USB.

THE VSG60A 6 GHz VECTOR SIGNAL GENERATOR – $2,480

Arbitrary I/Q sample rates from 12.5 kSPS to 51.2 MSPS
200 µs switch time for frequency hopping spread spectrum signal generation
40 MHz of real-time streaming bandwidth
Trigger output for syncing with other test equipment

THE BB60C 6 GHz SPECTRUM ANALYZER – $3,040

Real-time analysis with an IBW of 27 MHz
Up to 24 GHz/sec sweep speed
Dynamic range -158 dBm to +10 dBm

Signal Hound®

SignalHound.com

Made in the USA

BETTER **TOGETHER**

Little to no lead-time | Extended temperature options available

DEVELOPING AN IN-HOUSE EMC TROUBLESHOOTING AND PRE-COMPLIANCE TEST LAB

Kenneth Wyatt
Wyatt Technical Services LLC
ken@emc-seminars.com

While investing in your own full in-house EMC test laboratory may seem difficult to justify, most companies should be able to afford to implement some level of pre-compliance testing capability. Outside compliance test labs can cost upwards of $2,000 per day. The advantage of being able to perform some of the key tests in-house is that you can quickly determine whether your product is anywhere close to passing. Identifying "red flags" or problem areas early allows more cost-effective implementation of fixes. Waiting until the end of a product development cycle to determine EMC compliance is always very risky and usually expensive in time and money.

As a consultant, I frequently run into clients that have worked for weeks or months to beat down a radiated emissions problem by repeatedly cycling between their R&D lab and third-party compliance test lab. This is very frustrating for both the designers and their management. By performing some very quick and simple tests, you can identify failures, narrow down the root cause, and try various fixes well before taking the product in for full compliance testing.

DEVELOPING AN IN-HOUSE EMC TROUBLESHOOTING AND PRE-COMPLIANCE TEST LAB

Developing Your Own EMI Test Lab

So, what's involved in developing a basic EMC pre-compliance test lab? It's not nearly as expensive as you might think. For example, there are only four common test failures I run into regularly: radiated emissions (RE) is always the number one issue, followed by radiated immunity (RI), electrostatic discharge (ESD), and conducted emissions (CE). With few exceptions and assuming a good power line and I/O port filtering, many of the line- or I/O port-related immunity tests are lower risk and usually pass OK. However, some low-end Asian power supplies do have inadequate or non-existent line filtering, and so I've added the CE test, which is relatively easy to perform.

Briefly, radiated emissions measures the radiated E-fields emanating from the product, equipment, or system under test. There are worldwide limits on how much these emissions can be, depending on the environment the equipment I designed to work in.

Radiated immunity is a measure of how much external E-fields the product or system can tolerate from external sources like broadcast, cellular phones or two-way radios, etc. Electrostatic discharge is a test to see how immune the product or system is to external static discharges, usually from operators touching keypads or touch screens.

Conducted emissions is a measure of the broadband and narrow band noise conducting out the line cord from switch-mode power supplies.

EMI Troubleshooting versus Pre-Compliance Testing

There's a difference between general troubleshooting and pre-compliance testing. General troubleshooting is usually performed with a set of probes and a spectrum analyzer. The goal is to identify sources of harmonic energy and determine fixes that reduce the harmonic amplitudes. Here, we're mainly looking for relative changes.

Pre-compliance testing, on the other hand, attempts to duplicate the way the compliance tests are run to the best ability possible and to compare with actual test limits.

Here is a list of basic equipment required for these four tests:

1. **Radiated Emissions** — While an oscilloscope is very useful for determining rise times and ringing, a spectrum analyzer is really the desired instrument for most EMI troubleshooting and measurement. In addition, you'll want a set of near-field probes, a current probe, a calibrated (or uncalibrated — see *Note 1*) EMI antenna, and possibly a 20 dB gain broadband preamplifier to boost the signal from the probes.
2. **Radiated Immunity** — You'll need an RF generator that can tune the required frequency band and possibly an RF amplifier to boost the signal level.
3. **Electrostatic Discharge** — You'll need an ESD simulator.
4. **Conducted Emissions** — Conducted emissions testing is performed according to CISPR 11 or 22 and requires a LISN between the source of AC line (or DC) voltage and the product under test. A spectrum analyzer is connected to the 50-Ohm port and the conducted RF noise voltage is displayed on the analyzer. Different model LISNs are made for either AC or DC supply voltage.

All the above equipment may be purchased on the used market. There is also a new category of "affordable" equipment, as well as lab-quality level equipment, depending on your budget. Generally, most pre-compliance testing does not require very expensive equipment, but you also need to factor in some niceties, such as real-time spectrum analysis for signals that may only appear infrequently or signals, such as wireless communications, that may not display clearly on low-cost swept analyzers. More on this is described in our 2016 *Real-Time Spectrum Analyzer Guide* (*Reference 1*). In addition, there may be important reasons to stick with higher-end lab-quality equipment with their higher performance.

Radiated Emissions

Because radiated emissions is usually the most frequent test failure, most of your investment should be focused on this test. Even so, there is a wide range of test investment choices. For example, a basic troubleshooting test setup I use frequently, is merely an uncalibrated receiving antenna positioned at one end of a workbench, connected to a small bench top spectrum analyzer. The product under test is positioned at the other end of the work bench (*Figure 1*). Cables are attached to the EUT and various troubleshooting techniques are used to help pinpoint product design issues.

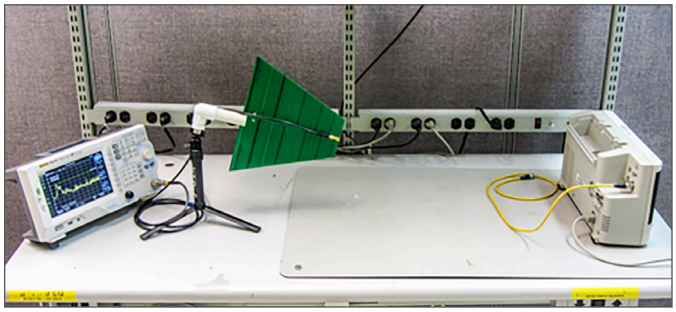


Figure 1. A typical troubleshooting test setup for radiated emissions.

Pre-compliance testing, requires a calibrated EMI antenna positioned either 1 m or (better) 3 m away from the product under test. This way, you'll be able to compare the emissions with actual test limits. The test may be set up in any area large enough and far away from other equipment that could interfere with the testing. Sometimes a parking lot is used. I've more often used a large conference room

(*Figure 2*). The one big issue in testing outside a shielded semi-anechoic chamber is you must deal with ambient signals — that is transmissions from broadcast radio/TV, cellular transmissions, and two-way radio.

Figure 2. An example of a 3 m pre-compliance test set up in a large conference room. Note the DIY turntable for helping maximize emissions.

Radiated Immunity

Radiated immunity testing may also be performed using simple troubleshooting techniques or in a shielded semi-anechoic chamber. Most of what I call "pre-compliance" testing is really just using an RF generator and near field probes, or a small Family Radio Service (FRS) license-free walkie-talkie. If the product under test can pass these simple tests, then it's also likely it will pass the formal tests at test levels of 3 V/m or 10 V/m (for commercial/industrial products). Military RI testing will more likely require much higher test levels that fall outside the scope of these simple bench top level tests.

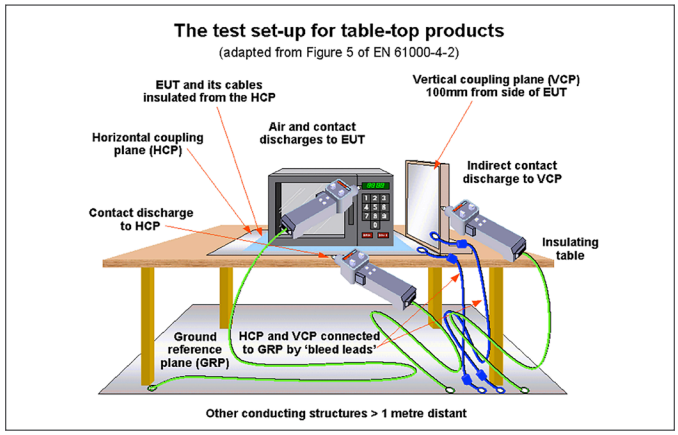


Figure 3. The ESD test setup according to IEC 6100-4-2. Image, courtesy Keith Armstrong.

Electrostatic Discharge

Electrostatic discharge pre-compliance testing can be performed on a work bench, but it's much better to duplicate the test table and ground planes as specified in the IEC 61000-4-2 test standard. This requires certain table dimensions with a conductive table surface and ground plane of certain size underneath. (*Figure 3*).

Conducted Emissions

Conducted emissions testing is performed according to CISPR 11 or 22 and requires a LISN between the source of AC line (or DC) voltage and the product under test. A spectrum analyzer is connected to the 50-Ohm port and the conducted RF noise voltage is displayed on the analyzer. Different model LISNs are made for either AC or DC supply voltage.

Summary

Investing in the equipment required to test and troubleshoot the most likely things that cause test failures is usually well worth the expense. Repeatedly moving back and forth between the R&D lab and compliance test lab can consume weeks of time and lead to project cost overruns.

Note on the Use of External Antennas

Note that there are two distinct goals when using external EMI antennas:

1. Relative troubleshooting, where you know areas of failing frequencies and need to reduce their amplitudes. A calibrated antenna is not required, as only relative changes are important. The antenna also does not necessarily need to be tuned to the frequency of the harmonics. Almost any "hunk of metal" connected to the spectrum analyzer should work. The important thing is that harmonic content from the EUT should be easily visible.
2. Pre-compliance testing, where you wish to duplicate the test setup as used by the compliance test lab. That is, setting up a calibrated antenna 3 m or 10 m away from the product or system under test and determining in advance whether you're passing or failing.

References

1. Real-Time Spectrum Analyzer Guide - https://interferencetechnology.com/wp-content/uploads/2016/10/2016-IT-Real-Time-Spectrum-Analyzer-Guide.pdf
2. List of recommended equipment - http://www.emc-seminars.com/EMI_Troubleshooting_Equipment_List-Wyatt.pdf

PROVIDING SOLUTIONS FOR
EMC COMPLIANCE

www.schaffnerusa.com
52 Mayfield Avenue I Edison, NJ 08837 I 800-367-5566

schaffner
shaping electrical power

COMMON COMMERCIAL EMC STANDARDS

Commercial Electromagnetic Compatibility (EMC) Standards

ANSI	
Document Number	Title
C63.4	Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz

IEC	
Document Number	Title
IEC 60050-161	International Electrotechnical Vocabulary. Chapter 161: Electromagnetic compatibility
IEC 60060-1	High-voltage test techniques. Part 1: General definitions and test requirements
IEC 60060-2	High-voltage test techniques - Part 2: Measuring systems
IEC 60060-3	High-voltage test techniques - Part 3: Definitions and requirements for on-site testing
IEC 60118-13	Electroacoustics - Hearing aids - Part 13: Electromagnetic compatibility (EMC)
IEC 60255-26	Measuring relays and protection equipment - Part 26: Electromagnetic compatibility requirements
IEC 60364-4-44	Low-voltage electrical installations - Part 4-44: Protection for safety - Protection against voltage disturbances and electromagnetic disturbance
IEC 60469	Transitions, pulses and related waveforms - Terms, definitions and algorithms
IEC 60533	Electrical and electronic installations in ships - Electromagnetic compatibility (EMC) - Ships with a metallic hull
IEC 60601-1-2	Medical electrical equipment - Part 1-2: General requirements for basic safety and essential performance - Collateral Standard: Electromagnetic disturbances - Requirements and tests
IEC 60601-2-2	Medical electrical equipment - Part 2-2: Particular requirements for the basic safety and essential performance of high frequency surgical equipment and high frequency surgical accessories
IEC 60601-4-2	Medical electrical equipment - Part 4-2: Guidance and interpretation - Electromagnetic immunity: performance of medical electrical equipment and medical electrical systems
IEC 60728-2	Cabled distribution systems for television and sound signals - Part 2: Electromagnetic compatibility for equipment
IEC 60728-12	Cabled distribution systems for television and sound signals - Part 12: Electromagnetic compatibility of systems

IEC (continued)	
Document Number	Title
IEC/TS 60816	Guide on methods of measurement of short duration transients on low-voltage power and signal lines
IEC 60870-2-1	Telecontrol equipment and systems - Part 2: Operating conditions - Section 1: Power supply and electromagnetic compatibility
IEC 60940	Guidance information on the application of capacitors, resistors, inductors and complete filter units for electromagnetic interference suppression
IEC 60974-10	Arc welding equipment - Part 10: Electromagnetic compatibility (EMC) requirements
IEC/TR 61000-1-1	Electromagnetic compatibility (EMC) - Part 1: General - Section 1: Application and interpretation of fundamental definitions and terms
IEC/TS 61000-1-2	Electromagnetic compatibility (EMC) - Part 1-2: General - Methodology for the achievement of the functional safety of electrical and electronic equipment with regard to electromagnetic phenomena
IEC/TR 61000-1-3	Electromagnetic compatibility (EMC) - Part 1-3: General - The effects of high-altitude EMP (HEMP) on civil equipment and systems
IEC/TR 61000-1-4	Electromagnetic compatibility (EMC) - Part 1-4: General - Historical rationale for the limitation of power-frequency conducted harmonic current emissions from equipment, in the frequency range up to 2 kHz
IEC/TR 61000-1-5	Electromagnetic compatibility (EMC) - Part 1-5: General - High power electromagnetic (HPEM) effects on civil systems
IEC/TR 61000-1-6	Electromagnetic compatibility (EMC) - Part 1-6: General - Guide to the assessment of measurement uncertainty
IEC/TR 61000-1-7	Electromagnetic compatibility (EMC) - Part 1-7: General - Power factor in single-phase systems under non-sinusoidal conditions
IEC/TR 61000-2-1	Electromagnetic compatibility (EMC) - Part 2: Environment - Section 1: Description of the environment - Electromagnetic environment for low-frequency conducted disturbances and signaling in public power supply systems
IEC 61000-2-2	Electromagnetic compatibility (EMC) - Part 2-2: Environment - Compatibility levels for low-frequency conducted disturbances and signaling in public low-voltage power supply systems
IEC/TR 61000-2-3	Electromagnetic compatibility (EMC) - Part 2: Environment - Section 3: Description of the environment - Radiated and non-network-frequency-related conducted phenomena

IEC (continued)	
Document Number	Title
IEC 61000-2-4	Electromagnetic compatibility (EMC) - Part 2-4: Environment - Compatibility levels in industrial plants for low-frequency conducted disturbances
IEC/TS 61000-2-5	Electromagnetic compatibility (EMC) - Part 2: Environment - Section 5: Classification of electromagnetic environments. Basic EMC publication
IEC/TR 61000-2-6	Electromagnetic compatibility (EMC) - Part 2: Environment - Section 6: Assessment of the emission levels in the power supply of industrial plants as regards low-frequency conducted disturbances
IEC/TR 61000-2-7	Electromagnetic compatibility (EMC) - Part 2: Environment - Section 7: Low frequency magnetic fields in various environments
IEC/TR 61000-2-8	Electromagnetic compatibility (EMC) - Part 2-8: Environment - Voltage dips and short interruptions on public electric power supply systems with statistical measurement results
IEC 61000-2-9	Electromagnetic compatibility (EMC) - Part 2: Environment - Section 9: Description of HEMP environment - Radiated disturbance. Basic EMC publication
IEC 61000-2-10	Electromagnetic compatibility (EMC) - Part 2-10: Environment - Description of HEMP environment - Conducted disturbance
IEC 61000-2-11	Electromagnetic compatibility (EMC) - Part 2-11: Environment - Classification of HEMP environments
IEC 61000-2-12	Electromagnetic compatibility (EMC) - Part 2-12: Environment - Compatibility levels for low-frequency conducted disturbances and signaling in public medium-voltage power supply systems
IEC 61000-2-13	Electromagnetic compatibility (EMC) - Part 2-13: Environment - High-power electromagnetic (HPEM) environments - Radiated and conducted
IEC/TR 61000-2-14	Electromagnetic compatibility (EMC) - Part 2-14: Environment - Overvoltages on public electricity distribution networks
IEC 61000-3-2	Electromagnetic compatibility (EMC) - Part 3-2: Limits - Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)
IEC 61000-3-3	Electromagnetic compatibility (EMC) – Part 3-3: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤ 16 A per phase and not subject to conditional connection
IEC/TS 61000-3-4	Electromagnetic compatibility (EMC) - Part 3-4: Limits - Limitation of emission of harmonic currents in low-voltage power supply systems for equipment with rated current greater than 16 A
IEC/TS 61000-3-5	Electromagnetic compatibility (EMC) - Part 3: Limits - Section 5: Limitation of voltage fluctuations and flicker in low-voltage power supply systems for equipment with rated current greater than 16 A
IEC/TR 61000-3-6	Electromagnetic compatibility (EMC) - Part 3: Limits - Section 6: Assessment of emission limits for distorting loads in MV and HV power systems - Basic EMC publication
IEC/TR 61000-3-7	Electromagnetic compatibility (EMC) - Part 3: Limits - Section 7: Assessment of emission limits for fluctuating loads in MV and HV power systems - Basic EMC publication
IEC 61000-3-8	Electromagnetic compatibility (EMC) - Part 3: Limits - Section 8: Signaling on low-voltage electrical installations - Emission levels, frequency bands and electromagnetic disturbance levels
IEC 61000-3-11	Electromagnetic compatibility (EMC) - Part 3-11: Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems - Equipment with rated current <= 75 A and subject to conditional connection

IEC (continued)	
Document Number	Title
IEC 61000-3-12	Electromagnetic compatibility (EMC) - Part 3-12: Limits - Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current >16 A and <=75 A per phase
IEC/TR 61000-3-13	Electromagnetic compatibility (EMC) - Part 3-13: Limits - Assessment of emission limits for the connection of unbalanced installations to MV, HV and EHV power systems
IEC/TR 61000-3-14	Electromagnetic compatibility (EMC) - Part 3-14: Assessment of emission limits for harmonics, interharmonics, voltage fluctuations and unbalance for the connection of disturbing installations to LV power systems
IEC/TR 61000-3-15	Electromagnetic compatibility (EMC) - Part 3-15: Limits - Assessment of low frequency electromagnetic immunity and emission requirements for dispersed generation systems in LV network
IEC TR 61000-4-1	Electromagnetic compatibility (EMC) - Part 4-1: Testing and measurement techniques - Overview of IEC 61000-4 series
IEC 61000-4-2	Electromagnetic compatibility (EMC)- Part 4-2: Testing and measurement techniques - Electrostatic discharge immunity test
IEC 61000-4-3	Electromagnetic compatibility (EMC) - Part 4-3 : Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field immunity test
IEC 61000-4-4	Electromagnetic compatibility (EMC) - Part 4-4 : Testing and measurement techniques – Electrical fast transient/burst immunity test
IEC 61000-4-5	Electromagnetic compatibility (EMC) - Part 4-5: Testing and measurement techniques - Surge immunity test
IEC 61000-4-6	Electromagnetic compatibility (EMC) - Part 4-6: Testing and measurement techniques - Immunity to conducted disturbances, induced by radio-frequency fields
IEC 61000-4-7	Electromagnetic compatibility (EMC) - Part 4-7: Testing and measurement techniques - General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto
IEC 61000-4-8	Electromagnetic compatibility (EMC) - Part 4-8: Testing and measurement techniques - Power frequency magnetic field immunity test
IEC 61000-4-9	Electromagnetic compatibility (EMC) - Part 4-9: Testing and measurement techniques - Impulse magnetic field immunity test
IEC 61000-4-10	Electromagnetic compatibility (EMC) - Part 4-10: Testing and measurement techniques - Damped oscillatory magnetic field immunity test
IEC 61000-4-11	Electromagnetic compatibility (EMC) - Part 4-11: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations immunity tests
IEC 61000-4-12	Electromagnetic compatibility (EMC) - Part 4-12: Testing and measurement techniques - Ring wave immunity test
IEC 61000-4-13	Electromagnetic compatibility (EMC) - Part 4-13: Testing and measurement techniques - Harmonics and interharmonics including mains signaling at a.c. power port, low frequency immunity tests
IEC 61000-4-14	Electromagnetic compatibility (EMC) - Part 4-14: Testing and measurement techniques - Voltage fluctuation immunity test
IEC 61000-4-15	Electromagnetic compatibility (EMC) - Part 4: Testing and measurement techniques - Section 15: Flickermeter - Functional and design specifications
IEC 61000-4-16	Electromagnetic compatibility (EMC) - Part 4-16: Testing and measurement techniques - Test for immunity to conducted, common mode disturbances in the frequency range 0 Hz to 150 kHz

IEC (continued)	
Document Number	Title
IEC 61000-4-17	Electromagnetic compatibility (EMC) - Part 4-17: Testing and measurement techniques - Ripple on d.c. input power port immunity test
IEC 61000-4-18	Electromagnetic compatibility (EMC) - Part 4-18: Testing and measurement techniques - Damped oscillatory wave immunity test
IEC 61000-4-19	Electromagnetic compatibility (EMC) - Part 4-19: Testing and measurement techniques - Test for immunity to conducted, differential mode disturbances and signalling in the frequency range 2 kHz to 150 kHz at a.c. power ports
IEC 61000-4-20	Electromagnetic compatibility (EMC) - Part 4-20: Testing and measurement techniques - Emission and immunity testing in transverse electromagnetic (TEM) waveguides
IEC 61000-4-21	Electromagnetic compatibility (EMC) - Part 4-21: Testing and measurement techniques - Reverberation chamber test methods
IEC 61000-4-22	Electromagnetic compatibility (EMC) - Part 4-22: Testing and measurement techniques - Radiated emissions and immunity measurements in fully anechoic rooms (FARs)
IEC 61000-4-23	Electromagnetic compatibility (EMC) - Part 4-23: Testing and measurement techniques - Test methods for protective devices for HEMP and other radiated disturbances
IEC 61000-4-24	Electromagnetic compatibility (EMC) - Part 4-24: Testing and measurement techniques - Test methods for protective devices for HEMP conducted disturbance
IEC 61000-4-25	Electromagnetic compatibility (EMC) - Part 4-25: Testing and measurement techniques - HEMP immunity test methods for equipment and systems
IEC 61000-4-27	Electromagnetic compatibility (EMC) - Part 4-27: Testing and measurement techniques - Unbalance, immunity test
IEC 61000-4-28	Electromagnetic compatibility (EMC) - Part 4-28: Testing and measurement techniques - Variation of power frequency, immunity test
IEC 61000-4-29	Electromagnetic compatibility (EMC) - Part 4-29: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations on d.c. input power port immunity tests
IEC 61000-4-30	Electromagnetic compatibility (EMC) – Part 4-30: Testing and measurement techniques – Power quality measurement methods
IEC 61000-4-31	Electromagnetic compatibility (EMC) - Part 4-31: Testing and measurement techniques - AC mains ports broadband conducted disturbance immunity test
IEC/TR 61000-4-32	Electromagnetic compatibility (EMC) - Part 4-32: Testing and measurement techniques - High-altitude electromagnetic pulse (HEMP) simulator compendium
IEC 61000-4-33	Electromagnetic compatibility (EMC) - Part 4-33: Testing and measurement techniques - Measurement methods for high-power transient parameters
IEC 61000-4-34	Electromagnetic compatibility (EMC) - Part 4-34: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current more than 16 A per phase
IEC TR 61000-4-35	Electromagnetic compatibility (EMC) - Part 4-35: Testing and measurement techniques - HPEM simulator compendium
IEC 61000-4-36	Electromagnetic compatibility (EMC) - Part 4-36: Testing and measurement techniques - IEMI immunity test methods for equipment and systems
IEC TR 61000-4-37	Electromagnetic compatibility (EMC) - Calibration and verification protocol for harmonic emission compliance test systems
IEC TR 61000-4-38	Electromagnetic compatibility (EMC) - Part 4-38: Testing and measurement techniques - Test, verification and calibration protocol for voltage fluctuation and flicker compliance test systems

IEC (continued)	
Document Number	Title
IEC/TR 61000-5-1	Electromagnetic compatibility (EMC) - Part 5: Installation and mitigation guidelines - Section 1: General considerations - Basic EMC publication
IEC/TR 61000-5-2	Electromagnetic compatibility (EMC) - Part 5: Installation and mitigation guidelines - Section 2: Earthing and cabling
IEC/TR 61000-5-3	Electromagnetic compatibility (EMC) - Part 5-3: Installation and mitigation guidelines - HEMP protection concepts
IEC/TS 61000-5-4	Electromagnetic compatibility (EMC) - Part 5: Installation and mitigation guidelines - Section 4: Immunity to HEMP - Specifications for protective devices against HEMP radiated disturbance. Basic EMC Publication
IEC 61000-5-5	Electromagnetic compatibility (EMC) - Part 5: Installation and mitigation guidelines - Section 5: Specification of protective devices for HEMP conducted disturbance. Basic EMC Publication
IEC/TR 61000-5-6	Electromagnetic compatibility (EMC) - Part 5-6: Installation and mitigation guidelines - Mitigation of external EM influences
IEC 61000-5-7	Electromagnetic compatibility (EMC) - Part 5-7: Installation and mitigation guidelines - Degrees of protection provided by enclosures against electromagnetic disturbances (EM code)
IEC 61000-5-8	Electromagnetic compatibility (EMC) - Part 5-8: Installation and mitigation guidelines - HEMP protection methods for the distributed infrastructure
IEC 61000-5-9	Electromagnetic compatibility (EMC) - Part 5-9: Installation and mitigation guidelines - System-level susceptibility assessments for HEMP and HPEM
IEC 61000-6-1	Electromagnetic compatibility (EMC) - Part 6-1: Generic standards - Immunity standard for residential, commercial and light-industrial environments
IEC 61000-6-2	Electromagnetic compatibility (EMC) - Part 6-2: Generic standards - Immunity standard for industrial environments
IEC 61000-6-3	Electromagnetic compatibility (EMC) - Part 6-3: Generic standards - Emission standard for residential, commercial and light-industrial environments
IEC 61000-6-4	Electromagnetic compatibility (EMC) - Part 6-4: Generic standards - Emission standard for industrial environments
IEC 61000-6-5	Electromagnetic compatibility (EMC) - Part 6-5: Generic standards - Immunity for power station and substation environments
IEC 61000-6-6	Electromagnetic compatibility (EMC) - Part 6-6: Generic standards - HEMP immunity for indoor equipment
IEC 61000-6-7	Electromagnetic compatibility (EMC) - Part 6-7: Generic standards - Immunity requirements for equipment intended to perform functions in a safety-related system (functional safety) in industrial locations
IEC 61326-1	Electrical equipment for measurement, control and laboratory use – EMC requirements – Part 1: General requirements
IEC 61326-2-1	Electrical equipment for measurement, control and laboratory use - EMC requirements - Part 2-1: Particular requirements - Test configurations, operational conditions and performance criteria for sensitive test and measurement equipment for EMC unprotected applications
IEC 61326-2-2	Electrical equipment for measurement, control and laboratory use - EMC requirements - Part 2-2: Particular requirements - Test configurations, operational conditions and performance criteria for portable test, measuring and monitoring equipment used in low-voltage distribution systems

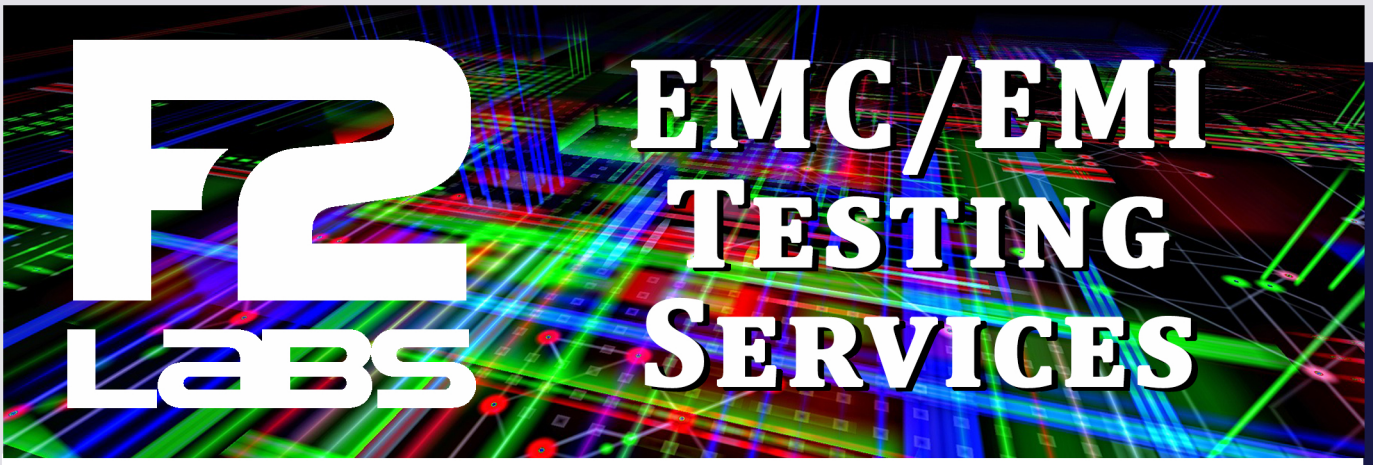
IEC (continued)	
Document Number	Title
IEC 61326-2-3	Electrical equipment for measurement, control and laboratory use - EMC requirements - Part 2-3: Particular requirements - Test configuration, operational conditions and performance criteria for transducers with integrated or remote signal conditioning
IEC 61326-2-4	Electrical equipment for measurement, control and laboratory use - EMC requirements - Part 2-4: Particular requirements - Test configurations, operational conditions and performance criteria for insulation monitoring devices according to IEC 61557-8 and for equipment for insulation fault location according to IEC 61557-9
IEC 61326-2-5	Electrical equipment for measurement, control and laboratory use - EMC requirements - Part 2-5: Particular requirements - Test configurations, operational conditions and performance criteria for field devices with field bus interfaces according to IEC 61784-1
IEC 61326-2-6	Electrical equipment for measurement, control and laboratory use - EMC requirements - Part 2-6: Particular requirements - In vitro diagnostic (IVD) medical equipment
IEC 61326-3-1	Electrical equipment for measurement, control and laboratory use - EMC requirements - Part 3-1: Immunity requirements for safety-related systems and for equipment intended to perform safety-related functions (functional safety) - General industrial applications
IEC 61326-3-2	Electrical equipment for measurement, control and laboratory use - EMC requirements - Part 3-2: Immunity requirements for safety-related systems and for equipment intended to perform safety-related functions (functional safety) - Industrial applications with specified electromagnetic environment
IEC 61340-3-1	Electrostatics - Part 3-1: Methods for simulation of electrostatic effects - Human body model (HBM) electrostatic discharge test waveforms
IEC 61543	Residual current-operated protective devices (RCDs) for household and similar use - Electromagnetic compatibility
IEC 61800-3	Adjustable speed electrical power drive systems - Part 3: EMC requirements and specific test methods
IEC 61967-1	Integrated circuits - Measurement of electromagnetic emissions, 150 kHz to 1 GHz - Part 1: General conditions and definitions
IEC 62040-2	Uninterruptible power systems (UPS) - Part 2: Electromagnetic compatibility EMC) requirements
IEC 62041	Power transformers, power supply units, reactors and similar products - EMC requirements
IEC 62153-4-0	Metallic communication cable test methods - Part 4-0: Electromagnetic compatibility (EMC) - Relationship between surface transfer impedance and screening attenuation, recommended limits
IEC 62153-4-1	Metallic communication cable test methods - Part 4-1: Electromagnetic compatibility (EMC) - Introduction to electromagnetic screening measurements
IEC 62153-4-2	Metallic communication cable test methods - Part 4-2: Electromagnetic compatibility (EMC) - Screening and coupling attenuation - Injection clamp method
IEC 62153-4-3	Metallic communication cable test methods - Part 4-3: Electromagnetic compatibility (EMC) - Surface transfer impedance - Triaxial method
IEC 62153-4-4	Metallic communication cable test methods - Part 4-4: Electromagnetic compatibility (EMC) - Test method for measuring of the screening attenuation as up to and above 3 GHz, triaxial method
IEC 62153-4-5	Metallic communication cables test methods - Part 4-5: Electromagnetic compatibility (EMC) - Coupling or screening attenuation - Absorbing clamp method

IEC (continued)	
Document Number	Title
IEC 62153-4-6	Metallic communication cable test methods - Part 4-6: Electromagnetic compatibility (EMC) - Surface transfer impedance - Line injection method
IEC 62153-4-7	Metallic communication cable test methods - Part 4-7: Electromagnetic compatibility (EMC) - Test method for measuring of transfer impedance ZT and screening attenuation aS or coupling attenuation aC of connectors and assemblies up to and above 3 GHz - Triaxial tube in tube method
IEC 62153-4-8	Metallic communication cable test methods - Part 4-8: Electromagnetic compatibility (EMC) - Capacitive coupling admittance
IEC 62153-4-9	Metallic communication cable test methods - Part 4-9: Electromagnetic compatibility (EMC) - Coupling attenuation of screened balanced cables, triaxial method
IEC 62153-4-10	Metallic communication cable test methods - Part 4-10: Electromagnetic compatibility (EMC) - Transfer impedance and screening attenuation of feed-throughs and electromagnetic gaskets - Double coaxial test method
IEC 62153-4-11	Metallic communication cable test methods - Part 4-11: Electromagnetic compatibility (EMC) - Coupling attenuation or screening attenuation of patch cords, coaxial cable assemblies, pre-connectorized cables - Absorbing clamp method
IEC 62153-4-12	Metallic communication cable test methods - Part 4-12: Electromagnetic compatibility (EMC) - Coupling attenuation or screening attenuation of connecting hardware - Absorbing clamp method
IEC 62153-4-13	Metallic communication cable test methods - Part 4-13: Electromagnetic compatibility (EMC) - Coupling attenuation of links and channels (laboratory conditions) - Absorbing clamp method
IEC 62153-4-14	Metallic communication cable test methods - Part 4-14: Electromagnetic compatibility (EMC) - Coupling attenuation of cable assemblies (Field conditions) absorbing clamp method
IEC 62153-4-15	Metallic communication cable test methods - Part 4-15: Electromagnetic compatibility (EMC) - Test method for measuring transfer impedance and screening attenuation - or coupling attenuation with triaxial cell
IEC 62236-1	Railway applications - Electromagnetic compatibility - Part 1: General
IEC 62236-2	Railway applications - Electromagnetic compatibility - Part 2: Emission of the whole railway system to the outside world
IEC 62236-3-1	Railway applications - Electromagnetic compatibility - Part 3-1: Rolling stock - Train and complete vehicle
IEC 62236-3-2	Railway applications - Electromagnetic compatibility - Part 3-2: Rolling stock - Apparatus
IEC 62236-4	Railway applications - Electromagnetic compatibility - Part 4: Emission and immunity of the signalling and telecommunications apparatus
IEC 62236-5	Railway applications - Electromagnetic compatibility - Part 5: Emission and immunity of fixed power supply installations and apparatus
IEC 62305-1	Protection against lightning - Part 1: General principles
IEC 62305-2	Protection against lightning - Part 2: Risk management
IEC 62305-3	Protection against lightning - Part 3: Physical damage to structures and life hazard

IEC (continued)	
Document Number	Title
IEC 62305-4	Protection against lightning - Part 4: Electrical and electronic systems within structures
IEC 62310-2	Static transfer systems (STS) - Part 2: Electromagnetic compatibility (EMC) requirements
IEC/TR 62482	Electrical installations in ships - Electromagnetic compatibility - Optimising of cable installations on ships - Testing method of routing distance

CISPR	
Document Number	Title
CISPR 11	Industrial, scientific and medical (ISM) radio-frequency equipment - Electromagnetic disturbance characteristics - Limits and methods of measurement
CISPR 12	Vehicles, boats and internal combustion engines - Radio disturbance characteristics - Limits and methods of measurement for the protection of off-board receivers
CISPR 14-1	Electromagnetic compatibility - Requirements for household appliances, electric tools and similar apparatus - Part 1: Emission
CISPR 14-2	Electromagnetic compatibility – Requirements for household appliances, electric tools and similar apparatus – Part 2: Immunity – Product family standard
CISPR 15	Limits and methods of measurement of radio disturbance characteristics of electrical lighting and similar equipment
CISPR 16-1-1	Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-1: Radio disturbance and immunity measuring apparatus - Measuring apparatus
CISPR 16-1-2	Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-2: Radio disturbance and immunity measuring apparatus - Coupling devices for conducted disturbance measurements
CISPR 16-1-3	Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-3: Radio disturbance and immunity measuring apparatus - Ancillary equipment - Disturbance power
CISPR 16-1-4	Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-4: Radio disturbance and immunity measuring apparatus - Antennas and test sites for radiated disturbance measurements
CISPR 16-1-5	Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-5: Radio disturbance and immunity measuring apparatus - Antenna calibration sites and reference test sites for 5 MHz to 18 GHz
CISPR 16-1-6	Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-6: Radio disturbance and immunity measuring apparatus - EMC antenna calibration
CISPR 16-2-1	Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-1: Methods of measurement of disturbances and immunity - Conducted disturbance measurements
CISPR 16-2-2	Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-2: Methods of measurement of disturbances and immunity - Measurement of disturbance power
CISPR 16-2-3	Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-3: Methods of measurement of disturbances and immunity - Radiated disturbance measurements

CISPR (continued)	
Document Number	Title
CISPR 16-2-4	Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-4: Methods of measurement of disturbances and immunity - Immunity measurements
CISPR TR 16-2-5	Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-5: In situ measurements for disturbing emissions produced by physically large equipment
CISPR TR 16-3	Specification for radio disturbance and immunity measuring apparatus and methods - Part 3: CISPR technical reports
CISPR TR 16-4-1	Specification for radio disturbance and immunity measuring apparatus and methods - Part 4-1: Uncertainties, statistics and limit modelling - Uncertainties in standardized EMC tests
CISPR TR 16-4-2	Specification for radio disturbance and immunity measuring apparatus and methods - Part 4-2: Uncertainties, statistics and limit modelling - Measurement instrumentation uncertainty
CISPR TR 16-4-3	Specification for radio disturbance and immunity measuring apparatus and methods - Part 4-3: Uncertainties, statistics and limit modelling - Statistical considerations in the determination of EMC compliance of mass-produced products
CISPR TR 16-4-4	Specification for radio disturbance and immunity measuring apparatus and methods - Part 4-4: Uncertainties, statistics and limit modelling - Statistics of complaints and a model for the calculation of limits for the protection of radio services
CISPR TR 16-4-5	Specification for radio disturbance and immunity measuring apparatus and methods - Part 4-5: Uncertainties, statistics and limit modelling - Conditions for the use of alternative test methods
CISPR 17	Methods of measurement of the suppression characteristics of passive EMC filtering devices
CISPR TR 18-1	Radio interference characteristics of overhead power lines and high-voltage equipment - Part 1: Description of phenomena
CISPR TR 18-2	Radio interference characteristics of overhead power lines and high-voltage equipment - Part 2: Methods of measurement and procedure for determining limits
CISPR TR 18-3	Radio interference characteristics of overhead power lines and high-voltage equipment - Part 3: Code of practice for minimizing the generation of radio noise
CISPR 20	Sound and television broadcast receivers and associated equipment - Immunity characteristics - Limits and methods of measurement (To be withdrawn in 2020)
CISPR 24	Information technology equipment - Immunity characteristics - Limits and methods of measurement (To be withdrawn in 2020)
CISPR 25	Vehicles, boats and internal combustion engines - Radio disturbance characteristics - Limits and methods of measurement for the protection of on-board receivers
CISPR 32	Electromagnetic compatibility of multimedia equipment – Emission requirements
CISPR 35	Electromagnetic compatibility of multimedia equipment - Immunity requirements



• What is EMC/EMI Testing?

• Why does my product need it? • Where do I start?

Our expert technical staff are here to help answer these questions and more. F2 Labs is an A2LA accredited laboratory that can guide you through the process of electrical product compliance testing that is required to get your product to market.

F2 Labs Performs EMC Testing for:

- CE Certification (EMC Directive and Radio Equipment Directive)
- FCC Certification
- FCC Supplier's Declaration of Conformity
- ISED Canada Certification
- RFID for Tires
- EMI Site Surveys
- And More

We can perform testing in our lab or at your facility. We also offer EMC pre-testing and Lab Time to make sure your product is ready for the full evaluation. Our goal is to get your product to market quickly.

LEARN MORE FROM THE EMC EXPERTS

CLICK OR CALL

F2LABS.COM | (877) 405 - 1580

MILITARY RELATED DOCUMENTS & STANDARDS

The following references are not intended to be all inclusive, but rather a representation of available sources of additional information and point of contacts.

MIL-HDBK-235-1D Military Operational Electromagnetic Environment Profiles Part 1D General Guidance, 03 April 2018.

MIL-HDBK-237D Electromagnetic Environmental Effects and Spectrum Certification Guidance for the Acquisition Process, 20 May 2005. (Notice 1 Validation 04 April 2013)

MIL-HDBK-240A Hazards of Electromagnetic Radiation to Ordnance (HERO) Test Guide, 10 Mar 2011.

MIL-HDBK-263B Electrostatic Discharge Control Handbook for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices), 31 Jul 1994.

MIL-HDBK-274A Electrical Grounding for Aircraft Safety, 14 Nov 2011. (Notice 1 Validation 16 August 2016)

MIL-HDBK-335 Management and Design Guidance Electromagnetic Radiation Hardness for Air Launched Ordnance Systems, Notice 4, 08 Jul 2008. (Notice 5 Cancellation 01 August 2013)

MIL-HDBK-419A Grounding, Bonding, and Shielding for Electronic Equipment and Facilities, 29 Dec 1987. (Notice 1 Validation 20 February 2014)

MIL-HDBK-454B General Guidelines for Electronic Equipment, 15 Apr 2007. (Notice 1 Validation 12 December 2012)

MIL-HDBK-1195, Radio Frequency Shielded Enclosures, 30 Sep 1988.

MIL-HDBK-2036 Preparation of Electronic Equipment Specifications, 1 November 1999

MIL-STD-188-124B Grounding, Bonding, and Shielding for Common Long Haul/Tactical Communications-Electronics Facilities and Equipment, 4 April 2013.

MIL-STD-220C Test Method Standard Method of Insertion Loss Measurement, 14 May 2009. (Notice 2 Validation 08 October 2019)

MIL-STD-331D Fuze and Fuze Components, Environmental and Performance Tests for, 31 May, 2017.

MIL-STD-449D Radio Frequency Spectrum Characteristics, Measurement of, 22 Feb 1973. (Notice 1 18 May 1976, Notice 2 Validation 04 April 2013)

MIL-STD-461F Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment, 10 Dec 2007.

MIL-STD-461G Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment, 11 Dec 2015.

MIL-STD-464C Electromagnetic Environmental Effects Requirements for Systems, 01 Dec 2010. (MIL-STD-464D to be released in 2020)

MIL-STD-704F Aircraft Electric Power Characteristics, Change Notice 1, 05 December 2016.

MIL-STD-1275E Characteristics of 28 Volt DC Power Input to Utilization Equipment in Military Vehicles, 22 March 2013 (MIL-STD-1275F expected release in 2020)

MIL-STD-1310H Standard Practice for Shipboard Bonding, Grounding, and Other Techniques for Electromagnetic Compatibility Electromagnetic Pulse (EMP) Mitigation and Safety, 17 Sep 2009. (Notice 1 Validation 12 August 2014)

MIL-STD-1377 Effectiveness of Cable, Connector, and Weapon Enclosure Shielding and Filters in Precluding Hazards of EM Radiation to Ordnance; Measurement of, 20 Aug 1971.

MIL-STD-1399 Section 300B Interface Standard for Shipboard Systems, Electric Power, Alternating Current, Cancelled 25 September 2018.

MIL-STD-1399 Section 300 Part 2 Medium Voltage Electric Power, Alternating Current, 25 September 2018

MIL-STD-1541A Electromagnetic Compatibility Requirements for Space Systems,Cancelled 27 April 2017.

MIL-STD-1542B Electromagnetic Compatibility and Grounding Requirements for Space System Facilities, 15 Nov 1991. MIL-STD-1605 Procedures for Conducting a Shipboard Electromagnetic Interference (EMI) Survey (Surface Ships), 15 Nov, 1991.

MIL-STD-1605A (SH) Procedures for Conducting a Shipboard Electromagnetic Interference (EMI) Survey (Surface Ships), 8 October 2009 (Validation Notice 1, 12 August 2014)

MIL-STD-1686C Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies, and Equipment (Excluding Electrically Initiated Explosive Devices). 25 Oct 1995.

ADS-37A-PRF Electromagnetic Environmental Effects (E3) Performance and Verification Requirements, 28 May 1996.

DOD-STD-1399 Section 070 Part 1 D.C. Magnetic Field Environment, Notice 1, 30 Nov 1989.

DoDI 3222.03 DoD Electromagnetic Environmental Effects (E3) Program, Change Notice 2, 10 October 2017. DoDD 4650.01 Policy and Procedures for Management and Use of the Electromagnetic Spectrum, 09 Jan 2009.

DoDI 6055.11 Protecting Personnel from Electromagnetic Fields, 19 Aug 2009.

TOP 01-2-511A Electromagnetic Environmental Effects System Testing, 20 November 2013

TOP 01-2-620 High-Altitude Electromagnetic Pulse (HEMP) Testing, 10 November 2011

TOP 01-2-622 Vertical Electromagnetic Pulse Testing, 11 September 2009

RF & Microwave Power Amplifiers

The World's Most Reliable High Performance Solid-State Amplifiers

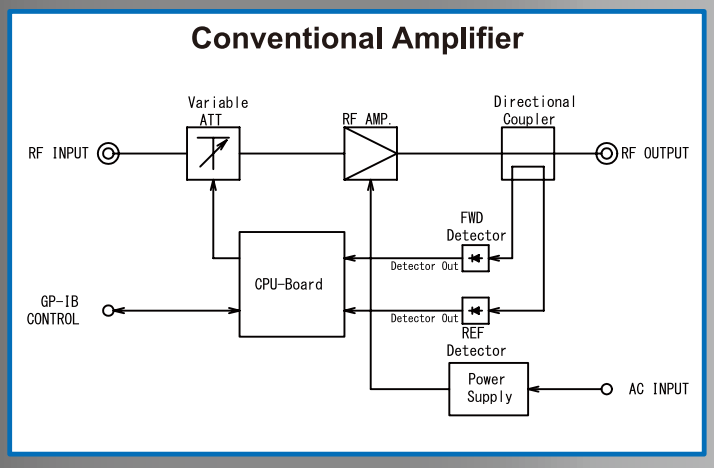
FS Amplifier

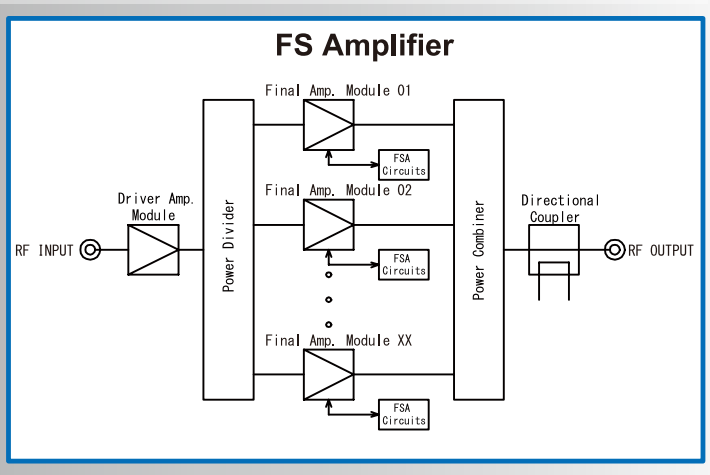
OPEN/SHORT TOLERANCE

•Virtually Unlimited Survival Time!

•Maximum Output Power!

The new FS Series of Class A solid state amplifiers from R&K incorporates an innovative "Fail-Safe Amplifier (FSA)" design. In the event of operational errors or load fluctuations, integrated reverse power protection FSA circuitry ensure the amplifier remains in a safe and damage free operational state under a wide range of load conditions.
The novel FSA design provides reverse power protection over a wide impedance range and extended periods of time without shutdown or severe output limitations.
Many other amplifier manufacturers make similar claims. But the new FS amplifier design, which leverages over 40 years of R&K RF design experience, delivers the highest reliability and performance of any impedance tolerant amplifier on the market.
Contact your local sales representative or R&K to learn more!





www.rk-microwave.com

Headquarters

R&K Company Limited

721-1 Maeda, Fuji-City, Shizuoka, 416-8577 Japan
Tel: +81-545-31-2600 Fax: +81-545-31-1600
Email: info@rkco.jp

US Sales Partner

CORNES Technologies USA

780 Montague Expy. Ste. 506 San Jose, CA 95131-1319 USA
Tel: +1-408-520-4550 Fax: +1-408-520-4551
Email: rkproducts@cornestech.com

AUTOMOTIVE ELECTROMAGNETIC COMPATIBILITY (EMC) STANDARDS

The following list of automotive EMC standards was developed by Dr. Todd Hubing, Professor Emeritus of Clemson University Vehicular Electronics Lab (http://www.cvel.clemson.edu/auto/auto_emc_standards.html). A few of these standards have been made public and are linked below, but many others are considered company confidential and are only available to approved automotive vendors or test equipment manufacturers.

While several standards are linked on this list, an internet search may help locate additional documents that have been made public. Permission to republish has been approved.

CISPR (Automotive Emissions Requirements)	
Document Number	Title
CISPR 12	Vehicles, boats, and internal combustion engine driven devices – Radio disturbance characteristics – Limits and methods of measurement for the protection of receivers except those installed in the vehicle/boat/device itself or in adjacent vehicles/boats/devices
CISPR 25	Radio disturbance characteristics for the protection of receivers used on board vehicles, boats, and on devices – Limits and methods of measurement
ISO (Automotive Immunity Requirements)	
Document Number	Title
ISO 7637-1	Road vehicles – Electrical disturbances from conduction and coupling – Part 1: Definitions and general considerations
ISO 7637-2	Road vehicles – Electrical disturbances from conduction and coupling – Part 2: Electrical transient conduction along supply lines only
ISO 7637-3	Road vehicles – Electrical disturbance by conduction and coupling – Part 3: Vehicles with nominal 12 V or 24 V supply voltage – Electrical transient transmission by capacitive and inductive coupling via lines other than supply lines
ISO/TR 10305-1	Road vehicles – Calibration of electromagnetic field strength measuring devices – Part 1: Devices for measurement of electromagnetic fields at frequencies > 0 Hz
ISO/TR 10305-2	Road vehicles – Calibration of electromagnetic field strength measuring devices – Part 2: IEEE standard for calibration of electromagnetic field sensors and probes, excluding antennas, from 9 kHz to 40 GHz
ISO 10605	Road vehicles – Test methods for electrical disturbances from electrostatic discharge
ISO/TS 14907-1	Road transport and traffic telematics – Electronic fee collection – Test procedures for user and fixed equipment – Part 1: Description of test procedures
ISO/TS 14907-2	Road transport and traffic telematics – Electronic fee collection – Test procedures for user and fixed equipment – Part 2: Conformance test for the onboard unit application interface
ISO/TS 21609	Road vehicles – (EMC) guidelines for installation of aftermarket radio frequency transmitting equipment
ISO 11451-1	Road vehicles – Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 1: General principles and terminology

ISO (Automotive Immunity Requirements) continued	
Document Number	Title
ISO 11451-2	Road vehicles – Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 2: Off-vehicle radiation sources
ISO 11451-3	Road vehicles – Electrical disturbances by narrowband radiated electromagnetic energy – Vehicle test methods – Part 3: On-board transmitter simulation
ISO 11451-4	Road vehicles – Vehicle test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 4: Bulk current injection (BCI)
ISO 11452-1	Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 1: General principles and terminology
ISO 11452-2	Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 2: Absorber-lined shielded enclosure
ISO 11452-3	Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 3: Transverse electromagnetic mode (TEM) cell
ISO 11452-4	Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 4: Bulk current injection (BCI)
ISO 11452-5	Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 5: Stripline
ISO 11452-7	Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 7: Direct radio frequency (RF) power injection
ISO 11452-8	Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 8: Immunity to magnetic fields
ISO 11452-10	Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 10: Immunity to conducted disturbances in the extended audio frequency range
ISO 11452-11	Road vehicles – Component test methods for electrical disturbances from narrowband radiated electromagnetic energy – Part 11: Reverberation chamber
ISO 13766	Earth-moving machinery – Electromagnetic compatibility

SAE (Automotive Emissions and Immunity)	
Document Number	Title
J1113/1	Electromagnetic Compatibility Measurement Procedures and Limits for Components of Vehicles, Boats (Up to 15 M), and Machines (Except Aircraft) (50 Hz to 18 Ghz)
J1113/2	Electromagnetic Compatibility Measurement Procedures and Limits for Vehicle Components (Except Aircraft)–Conducted Immunity, 15 Hz to 250 kHz–All Leads
J1113/3	Conducted Immunity, 250 kHz to 400 MHz, Direct Injection of Radio Frequency (RF) Power (Cancelled August 2010)
J1113/4	Immunity to Radiated Electromagnetic Fields-Bulk Current Injection (BCI) Method
J1113/11	Immunity to Conducted Transients on Power Leads
J1113/12	Electrical Interference by Conduction and Coupling – Capacitive and Inductive Coupling via Lines Other than Supply Lines
J1113/13	Electromagnetic Compatibility Measurement Procedure for Vehicle Components – Part 13: Immunity to Electrostatic Discharge
J1113/21	Electromagnetic Compatibility Measurement Procedure for Vehicle Components – Part 21: Immunity to Electromagnetic Fields, 30 MHz to 18 GHz, Absorber-Lined Chamber
J1113/24	Immunity to Radiated Electromagnetic Fields; 10 kHz to 200 MHz–Crawford TEM Cell and 10 kHz to 5 GHz–Wideband TEM Cell (Cancelled August 2010)
J1113/26	Electromagnetic Compatibility Measurement Procedure for Vehicle Components – Immunity to AC Power Line Electric Fields
J1113/27	Electromagnetic Compatibility Measurements Procedure for Vehicle Components – Part 27: Immunity to Radiated Electromagnetic Fields – Mode Stir Reverberation Method
J1113/28	Electromagnetic Compatibility Measurements Procedure for Vehicle Components–Part 28–Immunity to Radiated Electromagnetic Fields–Reverberation Method (Mode Tuning)
J1113/42	Electromagnetic Compatibility–Component Test Procedure–Part 42–Conducted Transient Emissions (Cancelled Dec 2010, Superseded by ISO 7637-2)
J1752/1	Electromagnetic Compatibility Measurement Procedures for Integrated Circuits-Integrated Circuit EMC Measurement Procedures-General and Definition
J1752/2	Measurement of Radiated Emissions from Integrated Circuits – Surface Scan Method (Loop Probe Method) 10 MHz to 3 GHz
J1752/3	Measurement of Radiated Emissions from Integrated Circuits – TEM/Wideband TEM (GTEM) Cell Method; TEM Cell (150 kHz to 1 GHz), Wideband TEM Cell (150 kHz to 8 GHz)
J551/5	Performance Levels and Methods of Measurement of Magnetic and Electric Field Strength from Electric Vehicles, Broadband, 9 kHz To 30 MHz
J551/11	Vehicle Electromagnetic Immunity–Off-Vehicle Source (Cancelled March 2010)

SAE (Automotive Emissions and Immunity) continued	
Document Number	Title
J551/12	Vehicle Electromagnetic Immunity–On-Board Transmitter Simulation (Cancelled August 2009)
J551/13	Vehicle Electromagnetic Immunity–Bulk Current Injection (Cancelled August 2009)
J551/15	Vehicle Electromagnetic Immunity–Electrostatic Discharge (ESD)
J551/16	Electromagnetic Immunity – Off-Vehicle Source (Reverberation Chamber Method) – Part 16 – Immunity to Radiated Electromagnetic Fields
J551/17	Vehicle Electromagnetic Immunity – Power Line Magnetic Fields
J1812	Function Performance Status Classification for EMC Immunity Testing
J2628	Characterization–Conducted Immunity
J2556	Radiated Emissions (RE) Narrowband Data Analysis–Power Spectral Density (PSD)

GM	
Document Number	Title
GMW3091	General Specification for Vehicles, Electromagnetic Compatibility (EMC)-Engl; Revision H; Supersedes GMI 12559 R and GMI 12559 V
GMW3097	General Specification for Electrical/Electronic Components and Subsystems, Electromagnetic Compatibility-Engl; Revision H; Supersedes GMW12559, GMW3100, GMW12002R AND GMW12002V
GMW3103	General Specification for Electrical/Electronic Components and Subsystems, Electromagnetic Compatibility Global EMC Component/Subsystem Validation Acceptance Process-Engl; Revision F; Contains Color; Replaces GMW12003, GMW12004 and GMW3106

Ford	
Document Number	Title
EMC-CS-2009.1	Component EMC Specification EMC-CS-2009.1
FORD F-2	Electrical and Electronics System Engineering
FORD WSF-M22P5-A1	Printed Circuit Boards, PTF, Double Sided, Flexible

DaimlerChrysler	
Document Number	Title
DC-10614	EMC Performance Requirements – Components
DC-10615	Electrical System Performance Requirements for Electrical and Electronic Components
DC-11224	EMC Performance Requirements – Components
DC-11225	EMC Supplemental Information and Alternative Component Requirements

Other Automotive Manufacturers	
Audi TL 82466	Electrostatic Discharge
BMW 600 13.0	Electric- / Electronic components in cars
BMW GS 95002	Electromagnetic Compatibility (EMC) Requirements and Tests
BMW GS 95003-2	Electric- / Electronic assemblies in motor vehicles
Chrysler PF 9326	Electrical electronic modules and motors
FIAT 9.90110	Electric and electronic devices for motor vehicles
Freightliner 49-00085	EMC Requirements
Honda 3838Z-S5AA-L000	Noise Simulation Test
Honda 3982Z-SDA-0030	Battery Simulation Test
Hyundai/Kia ES 39110-00	EMC Requirements
Hyundai/Kia ES-95400-10	Battery Simulation Tests
Hyundai/Kia ES 96100-01	EMC Requirements
IVECO 16-2103	EMC Requirements
Lotus 17.39.01	Lotus Engineering Standard: Electromagnetic Compatibility
Mack Trucks 606GS15	EMC Requirements
MAN 3285	EMC Requirements
Mazda MES PW 67600	Automobile parts standard (electronic devices)
Mercedes A 211 000 42 99	Instruction specification of test method for E/E-components
Mercedes AV EMV	Electric aggregate and electronics in cars
Mercedes MBN 10284-2	EMC requirements and tests of E/E-systems (component test procedures)
Mercedes MBN 22100-2	Electric / electronic elements, devices in trucks
Mitsubishi ES-X82010	General specification of environment tests on automotive electronic equipment
Nissan 28401 NDS02	EMC requirements (instruction concerning vehicle and electrical ...)
Nissan 28400 NDS03	Low frequency surge resistance of electronic parts
Nissan 28400 NDS04	Burst and Impulse Waveforms
Nissan 28400 NDS07	Immunity against low frequency surge (induction surge) of electronic parts
Peugeot B217110	Load Dump Pulses
Porsche AV EMC EN	EMC Requirements
PSA B21 7090	EMC Requirements (electric and electronics equipment)
PSA B21 7110	EMC requirements (electric and electronics equipment)
Renault 36.00.400	Physical environment of electrical and electronic equipments
Renault 36.00.808	EMC requirements (cars and electrical / electronic components)
Scania TB1400	EMC Requirements
Scania TB1700	Load Dump Test

Other Automotive Manufacturers	
Smart DE10005B	EMC requirements (electric aggregate and electronics in cars)
Toyota TSC7001G	Engineering standard (electric noise of electronic devices)
Toyota TSC7001G-5.1	Power Supply Voltage Characteristic Test
Toyota TSC7001G-5.2	Field Decay Test
Toyota TSC7001G-5.3	Floating Ground Test
Toyota TSC7001G-5.4	Induction Noise Resistance
Toyota TSC7001G-5.5.3	Load Dump Test-1
Toyota TSC7001G-5.5.4	Load Dump Test-2
Toyota TSC7001G-5.5.5	Load Dump Test-3
Toyota TSC7001G-5.6	Over Voltage Test
Toyota TSC7001G-5.7.3	Ignition Pulse (Battery Waveforms) Test-1
Toyota TSC7001G-5.7.4	Ignition Pulse (Battery Waveforms) Test-2
Toyota TSC7001G-5.8	Reverse Voltage
Toyota TSC7006G-4.4.2	Wide Band-Width Antenna Nearby Test (0.4 to 2 GHz)
Toyota TSC7006G-4.4.3	Radio Equipment Antenna nearby Test (28 MHz ...)
Toyota TSC7006G-4.4.4	Mobile Phone Antenna Nearby Test (835 MHz ...)
Toyota TSC7018G	Static Electricity Test
Toyota TSC7025G-5	TEM Cell Test (1 to 400 MHz)
Toyota TSC7025G-6	Free Field Immunity Test (20 MHz to 1 GHz AM, 0.8 to 2 GHz PM)
Toyota TSC7025G-7	Strip Line Test (20 - 400 MHz)
Toyota TSC7026G-3.4	Narrow Band Emissions
Toyota TSC7203G	Voltage Drop / Micro Drops
Toyota TSC7508G-3.3.1	Conductive Noise in FM and TV Bands
Toyota TSC7508G-3.3.2	Conductive noise in LW, AM and SW Bands
Toyota TSC7508G-3.3.3	Radiated Noise in FM and TV Bands
Toyota TSC7508G-3.3.4	Radiated Noise in AM, SW, and LW Bands
Toyota TSC7203G	Engineering standard (ABS-TRC computers)
Toyota TXC7315G	Electrostatic Discharge (Gap Method)
Visteon ES-XU3F-1316-AA	Electronic Component - Subsystem Electromagnetic Compatibility (EMC) Requirements and Test Procedures
Volvo EMC Requirements	EMC requirements for 12V and 24V systems
Volkswagen VW TL 801 01	Electric and electronic components in cars
Volkswagen VW TL 820 66	Conducted Interference
Volkswagen VW TL 821 66	EMC requirements of electronic components - bulk current injection (BCI)
Volkswagen VW TL 823 66	Coupled Interference on Sensor Cables
Volkswagen VW TL 824 66	Immunity Against Electrostatic Discharge
Volkswagen VW TL 965	Short-Distance Interference Suppression

CPI: Powering Your World

TWTAs for EMC applications

1.0–18.0 GHz up to 1000 W CW (10 kW available over select bands)

18.0–40.0 GHz up to 150 W (2.0 kW over select bands)

40.0–50.0 GHz up to 80 W

Full Pulsed Amplifier Suites to 8 kW (megawatts pulsed power capability)

Meet the latest automotive and military EMC standards with CPI high-powered TWT amplifiers.

EMC facilities worldwide depend on CPI amplifiers for superior performance, reliability, and quality. CPI has a proven track record of consistent performance, service, and support. For EMC testing, CPI is the only manufacturer of both the TWT and the amplifier, ensuring quality designs and smooth operation. CW and pulsed amplifiers are available from 1 to 95 GHz, with power levels exceeding 2 kW over selected frequencies.

For more information please contact:
Communications & Power Industries Canada,Inc.
45 River Drive, Georgetown, Ontario,Canada L7G 2J4
For Sales offices worldwide please e-mail:
satcommarketing@.cpii.com
Or look us up on the Web at: **www.cpii.com/emc**

CPI Communications & Power Industries

USEFUL EMC TESTING REFERENCES
(DIRECTORY, BOOKS, ORGANIZATIONS, LINKEDIN GROUPS)

RECOMMENDED BOOKS & JOURNALS

RECOMMENDED BOOKS

André and Wyatt
EMI Troubleshooting Cookbook for Product Designers
SciTech Publishing, 2014.
Includes chapters on product design and EMC theory & measurement. A major part of the content includes how to troubleshoot and mitigate all common commercial EMC test failures.

Archambeault
PCB Design for Real-World EMI Control
Kluwer Academic Publishers, 2002.

Bogatin
Signal & Power Integrity - Simplified
Prentice-Hall, 2018 (3rd Edition).
Great coverage of signal and power integrity from a fields viewpoint.

Hall, Hall, and McCall
High-Speed Digital System Design - A Handbook of Interconnect Theory and Design Practices
Wiley, 2000.

Joffe and Lock
Grounds For Grounding
Wiley, 2010.
This huge book includes way more topics on product design than the title suggests. Covers all aspects of grounding and shielding for products, systems, and facilities.

Johnson and Graham
High-Speed Digital Design - A Handbook of Black Magic
Prentice-Hall, 1993.
Practical coverage of high speed digital signals and measurement.

Johnson and Graham
High-Speed Signal Propagation - Advanced Black Magic
Prentice-Hall, 2003.
Practical coverage of high speed digital signals and measurement.

Kimmel and Gerke
Electromagnetic Compatibility in Medical Equipment
IEEE Press, 1995.
Good general product design information.

Mardiguian
EMI Troubleshooting Techniques
McGraw-Hill, 2000.
Good coverage of EMI troubleshooting.

Mardiguian
Controlling Radiated Emissions by Design
Springer, 2016.
Good content on product design for compliance.

Montrose
EMC Made Simple
Montrose Compliance Services, 2014.
The content includes several important areas of EMC theory and product design, troubleshooting, and measurement.

Morrison
Digital Circuit Boards - Mach 1 GHz
Wiley, 2012.
Important concepts of designing high frequency circuit boards from a fields viewpoint.

Morrison
Grounding And Shielding - Circuits and Interference
Wiley, 2016 (6th Edition).
The classic text on grounding and shielding with up to date content on how RF energy flows through circuit boards.

Morrison
Fast Circuit Boards
Wiley, 2018.
Morrison explains how signals propagate via transmission lines and why it's so important to include reference planes for every signal layer.

Ott
Electromagnetic Compatibility Engineering
Wiley, 2009.
The "bible" on EMC measurement, theory, and product design.

Paul
Introduction to Electromagnetic Compatibility
Wiley, 2006 (2nd Edition).
The one source to go to for an upper-level course on EMC theory.

USEFUL EMC TESTING REFERENCES (CONTINUED)
(DIRECTORY, BOOKS, ORGANIZATIONS, LINKEDIN GROUPS)

RECOMMENDED BOOKS (CONTINUED)

Sandler
Power Integrity - Measuring, Optimizing, and Troubleshooting Power Related Parameters in Electronics Systems
McGraw-Hill, 2014.
The latest information on measurement and design of power distribution networks and how the network affects stability and EMC.

Smith and Bogatin
Principles of Power Integrity for PDN Design - Simplified
Prentice-Hall, 2017.
Getting the power distribution network (PDN) design right is the key to reducing EMI.

Williams
EMC For Product Designers
Newnes, 2017.
Completely updated text on product design for EMC compliance.

Weston
Electromagnetic Compatibility - Methods, Analysis, Circuits, and Measurement
CRC Press, 2017 (3rd Edition).
A comprehensive text, primarily focused on military EMC.

Wyatt
EMC Desk Reference
Interference Technology, 2017.
A handy guide with technical articles and pertinent EMC reference information.

Wyatt & Jost
Electromagnetic Compatibility (EMC) Pocket Guide
SciTech Publishing, 2013.
A handy pocket-sized reference guide to EMC.

EMC STANDARDS ORGANIZATION

ANSI
http://www.ansi.org

ANSI Accredited C63
http://c63.org/index.htm

IEEE Standards Association
http://standards.ieee.org
SAE
http://www.sae.org

SAE EMC Standards Committee
http://www.sae.org/standards/

IEC
http://iec.ch

CISPR
http://www.iec.ch/emc/iec_emc/iec_emc_players_cispr.htm

ETSI
http://www.etsi.org

LINKEDIN GROUPS

EMC Experts

EMC Testing and Compliance

Electromagnetic Compatibility Forum

ESD Experts

EMC Troubleshooters

2021 EMC LIVE: Testing brings experts in EMC testing straight to your computer, speaking on topics like new and updated testing standards, testing equipment and components, and pre-compliance testing processes. Stay ahead of the testing curve, available now online FREE.

All for **FREE**. Are you ready?

www.emc.live/2021-event/testing/

PRESENTED BY INTERFERENCE TECHNOLOGY

EMC & DESIGN CONFERENCES 2021

The following is a partial listing of major EMC and electronics design conferences planned for 2020 in order of date. If your conference is not listed, please contact: James@lectrixgroup.com

EMC & COMPLIANCE INTERNATIONAL 2021 VIRTUAL EVENT
May 19 to June 30, 2021
Online Event
https://www.emcuk.co.uk/emcuk-2021
For 2021, we are hosting a unique virtual event, which is designed to augment the next 'real' event which will be held in May 2022.

IMS (INTERNATIONAL MICROWAVE SYMPOSIUM) 2021 (In-Person Event)
June 7, 2021
Georgia World Congress Center in Atlanta, Georgia
https://ims-ieee.org/
The IEEE Microwave Theory and Techniques Society's 2021 International Microwave Symposium (IMS2021) will be held June 7–10, 2021 at the Georgia World Congress Center in Atlanta, Georgia. You are cordially invited to join us in Atlanta at the intersection of communications, aerospace, automotive, IoT and other emerging technologies to learn the latest developments in MHz-to-THz theories, techniques, devices, systems, and applications. IMS2021 is the centerpiece of Microwave Week 2021 which is comprised of three conferences including the RFIC Symposium (www.rfic-ieee.org) and the ARFTG Conference (www.arftg.org)

APEC 2021
June 14-17, 2021
Online Event
https://apec-conf.org/
APEC is the leading conference for practicing power electronics professionals and addresses a broad range of topics in the use, design, manufacture, and marketing of all kinds of power electronics equipment.

NTERNATIONAL MICROWAVE SYMPOSIUM (Virtual Event)
June 20-25, 2021
Online Event
https://ims-ieee.org/
While our goal remains to have an in-person event, we recognize that attendance in Atlanta may not be possible for everyone. We want to make sure IMS2021 and Microwave Week are available to anyone who would like to participate, so we will have a virtual event two weeks after the in-person one in Atlanta. This event will feature all the content from the in-person event as well as some new content. As a special thank you to our in-person attendees who pick up their badges in Atlanta, we will provide a complimentary virtual events pass at the same level that they registered for in Atlanta. The IMS2021 Virtual Event will continue to be available in an on-demand format through July 2, 2021.

LECTRIX®

THERE'S ONLY ONE SPOTLIGHT

ARE YOU IN IT?

www.lectrixgroup.com

Problem first. Product last.

PHILADELPHIA | HONG KONG

INDEX OF ADVERTISERS

A.H. Systems
9710 Cozycroft Ave.
Chatsworth, CA 91311
t: (818) 998-0223
e: sales@ahsystems.com
w: www.AHSystems.com
page: 13

CPI
Communications & Power Industries
45 River Drive, Georgetown,
Ontario, Canada L7G 2J4
t: (905) 702-2228
e: satcommarketing@cpii.com
w: www.cpii.com
page: 35

EMC LIVE
1000 Germantown Pike
Plymouth Meeting, PA 19462
t: (484) 688-0300
w: www.lectrixgroup.com
e: james@lectrixgroup.com
page: 38

Exodus Advanced Communications
3674 East Sunset Road, Suite 100
Las Vegas, NV 89120
t: (702) 534-6564
e: EUSales@exoduscomm.com
w: www.exoduscomm.com
page: 4

F2 Laboratories
16740 Peters Rd
Middlefield, OH 44062
t: (440) 632-5541
e: sales@f2labs.com
w: www.f2labs.com
page:28

LECTRIX
1000 Germantown Pike
Plymouth Meeting, PA 19462
t: (484) 688-0300
e: james@lectrixgroup.com
w: www.lectrixgroup.com
page: 40

R&K Company Limited
721-1 Maeda, Fuji-city, Shizuoka-pref.
416-8577 JAPAN
t: +81-545-31-2600
e: info@rkco.jp
w: www.rk-microwave.com/index.php
page: 31

Rohde & Schwarz GmbH & Co. KG
Muehldorfstrasse 15
81671 Munich, Germany
t: +49 8004 0108 88
w: www.rohde-schwarz.com
page: 2

Rohde & Schwarz USA, Inc.
6821 Benjamin Franklin Drive
Columbia, MD 21046
t: (888) 837-8772
w: www.rohde-schwarz.com
page: 2

Schaffner EMC, Inc
52 Mayfield Avenue
Edison NJ, 08837, U.S
t: (800) 367-5566
e: usasales@schaffner.com
w: www.schaffnerusa.com
page: 22

Signal Hound
1502 SE Commerce Ave, Suite 101
Battle Ground, WA, 98604
t: (360) 313-7997
e: sales@signalhound.com
w: https://signalhound.com
page: 18

Würth Elektronik
Max-Eyth-Str. 1
74638 Waldenburg, Germany
t: +49 7942 945 - 0
e: eiSos@we-online.de
w: www.we-online.com
page: 7