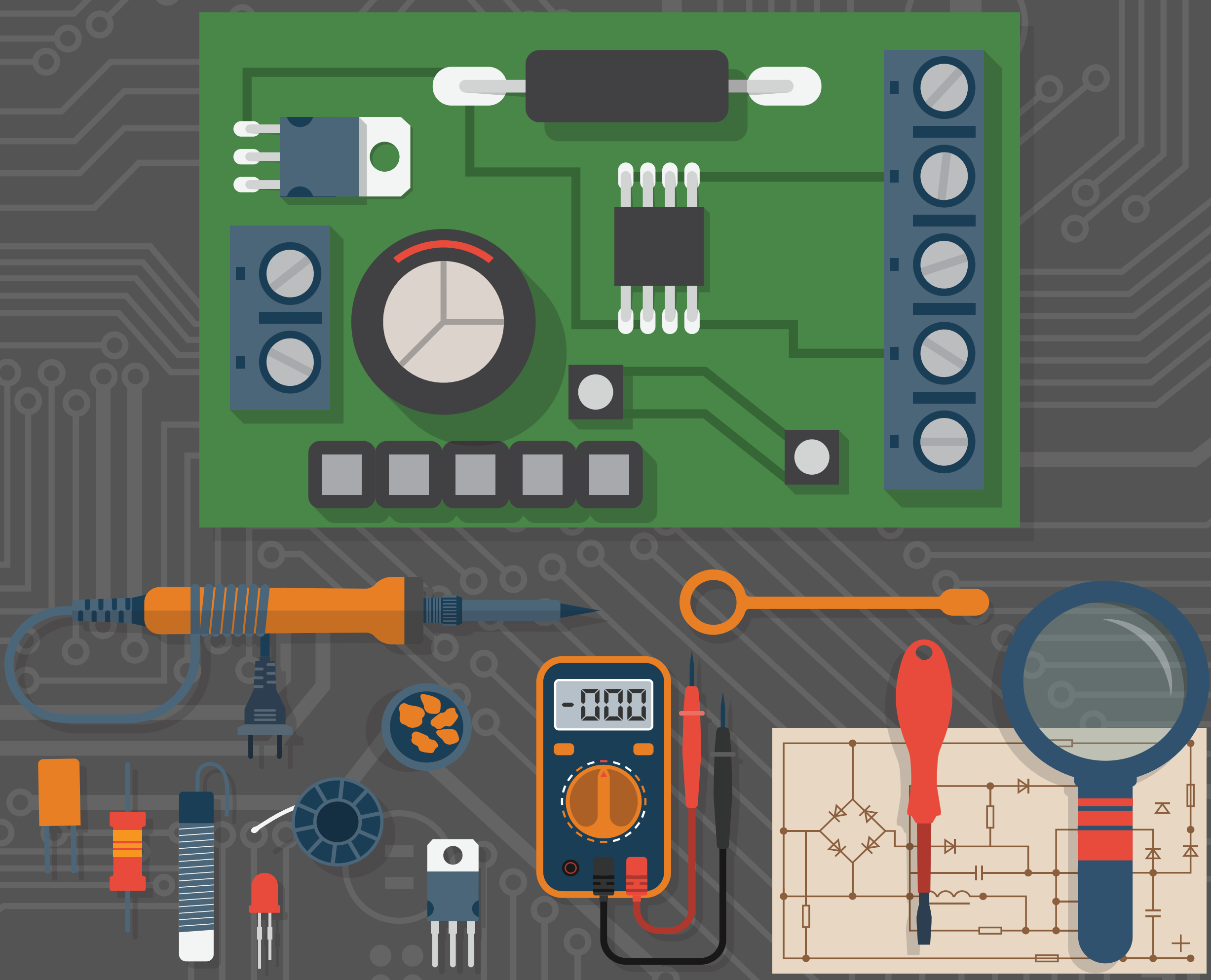
PRESENTED BY

INTERFERENCE TECHNOLOGY®

2017 EMC PRE-COMPLIANCE TEST GUIDE



PRE-COMPLIANCE GROUPS AND ORGANIZATIONS

EMC & DESIGN CONFERENCES

USEFUL EMC PRE-COMPLIANCE REFERENCES

DEVELOPING AN IN-HOUSE TROUBLESHOOTING AND PRE-COMPLIANCE TEST LAB
Kenneth Wyatt

EMI TROUBLESHOOTING - STEP-BY-STEP
Kenneth Wyatt

TABLE OF CONTENTS

INTRODUCTION

By Kenneth Wyatt
Editor, Interference Technology

This new 2017 EMC Pre-Compliance Test Guide describes how to set up a basic lab to perform EMC pre-compliance testing in-house. There are many advantages in performing at least a basic set of tests prior to using a third-party compliance test lab as I'll describe later, but cost and time savings are certainly the biggest benefit.

So, how does pre-compliance testing compare with compliance testing? Formal compliance testing requires the test lab to follow specific test procedures and test levels according to internationally-recognized EMC standards. It also requires a substantial investment in test equipment. A full compliance test lab can easily run into several million dollars - especially, if a full-sixe 10m semi-anechoic chamber is part of the equation.

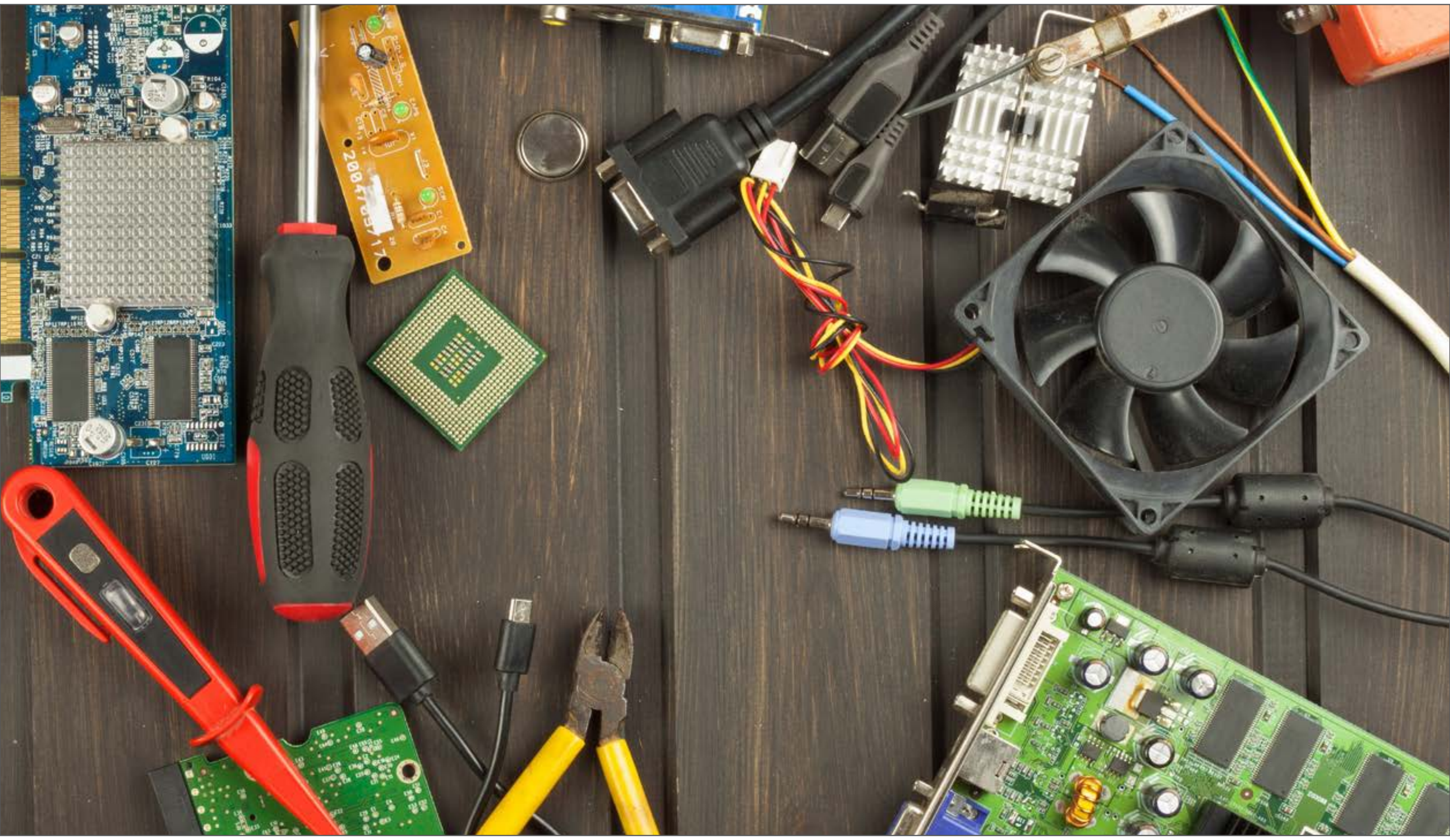
On the other hand, a pre-compliance test lab can be developed for between $10k and $750k, depending on the quality and feature set of the test equipment and whether a smaller 3m semi-anechoic chamber is built. If only a few key tests are desired, it's possible to develop your test lab somewhere near the lower end of this range.

This new guide will take you through the decision steps in developing an appropriate pre-compliance lab, describe the basic steps in identifying and troubleshooting the most common EMC issues, and provide some valuable reference information.

PRE-COMPLIANCE SUPPLIER GUIDE

Introduction

Your quick reference guide by various EMC pre-compliance test equipment types. The listing includes everything you'll need from the bare minimum required for key evaluation testing and probing, and troubleshooting, to setting up a full pre-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. 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.



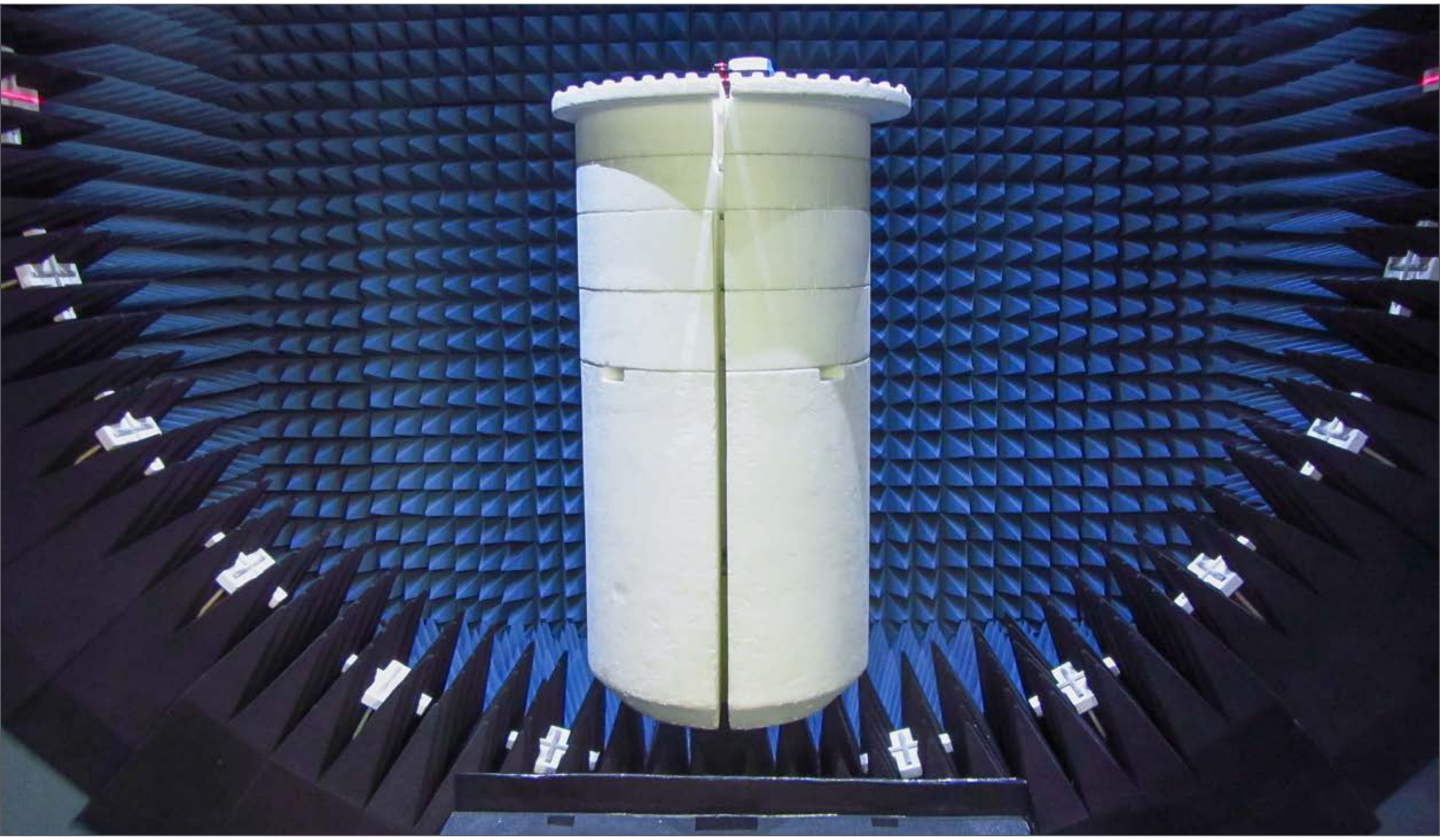
PRE-COMPLIANCE SUPPLIER GUIDE		TYPE OF PRODUCT/SERVICE												
Manufacturer	Contact Information - URL	Amplifiers	Antennas	Conducted Immunity	Current Probes	ESD Simulators	LISNs	Near Field Probes	Pre-Compliance Test	Radiated Immunity	Rental Companies	RF Signal Generators	Spectrum Analyzers/ EMI Receivers	TEM Cells
Aaronia AG	http://www.aaronia.com	X	X						X				X	
Advanced Test Equipment Rentals	http://www.atecorp.com/category/emc-compliance-esd-rfi-emi.aspx	X	X	X		X	X		X	X	X	X	X	
A.H. Systems	http://www.ahsystems.com	X	X		X				X					
Amplifier Research (AR)	https://www.amplifiers.com	X	X	X			X		X	X		X	X	
Anritsu	http://anritsu17-px.rtrk.com/en-US/test-measurement/industries/automotive/								X			X	X	
Electro Rent	http://www.electrorent.com	X		X		X	X		X	X	X	X	X	
EM Test	http://www.emtest.com/home.php			X					X					X
EMC Partner	https://www.emc-partner.com			X		X								
Empower RF Systems	http://www.empowerrf.com	X								X				
Emscan	http://www.emscan.com								X					
Fischer Custom Communications	http://www.fischercc.com				X			X						X
Gauss Instruments	https://www.gauss-instruments.com/en/												X	
Haefley-Hippotronics	http://www.haefely-hipotronics.com			X		X								
Instrument Rental Labs	http://www.testequip.com	X		X		X	X		X	X	X	X	X	
Instruments For Industry (IFI)	http://www.ifi.com	X		X						X				
Kent Electronics	http://www.wa5vjb.com		X											
Keysight Technologies	http://www.keysight.com/main/home.jspx?cc=US&lc=eng						X	X	X			X	X	
Langer-EMV	https://www.langer-emv.de/en/index			X				X	X					
Microlease	https://www.microlease.com/us/home	X		X		X	X		X	X	X	X	X	
Milmega	http://www.milmega.co.uk	X		X						X				
Narda/PMM	http://www.narda-sts.it/narda/default_en.asp	X	X	X			X		X	X			X	
Noiseken	http://www.noiseken.com			X		X			X					
Ophir RF	http://ophirrf.com	X		X										
Pearson Electronics	http://www.pearsonelectronics.com				X									
Rigol Technologies	https://www.rigolna.com				X			X	X			X	X	
Rohde & Schwarz	https://www.rohde-schwarz.com/us/home_48230.html	X	X	X	X		X	X	X	X		X	X	
Siglent Technologies	http://siglentamerica.com							X	X			X	X	
Signal Hound	https://signalhound.com							X	X			X	X	
Solar Electronics	http://www.solar-emc.com			X	X									
TekBox Technologies	https://www.tekbox.net	X					X	X	X					X
Tektronix	http://www.tek.com							X	X				X	
Teseq	http://www.teseq.com/en/index.php	X		X	X	X			X	X				X
Test Equity	https://www.testequity.com/leasing/	X		X		X	X		X	X	X	X	X	
ThermoFisher	https://www.thermofisher.com/us/en/home.html			X		X								
Thurlby Thandar (AIM-TTi)	http://www.aimtti.us								X			X	X	
Toyotech (Toyo)	https://toyotechus.com/emc-electromagnetic-compatibility/	X	X				X		X	X			X	
TPI	http://www.rf-consultant.com											X		
Transient Specialists	http://www.transientspecialists.com			X						X				X
TRSRenTelCo	https://www.trs-rentelco.com/SubCategory/EMC_Test_Equipment.aspx	X	X	X			X		X	X	X	X	X	
Vectawave Technology	http://vectawave.com	X												
Windfreak Technologies	https://windfreaktech.com											X		

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 pre-amplifier 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 (described above) 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.

I'll describe the various decisions and tradeoffs in more detail in the article, EMI Troubleshooting - Step-By-Step. I also have a suggested list of basic test equipment on my web site (*Reference 2*).

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 (see EMI Troubleshooting Step-By-Step for recommended procedures).

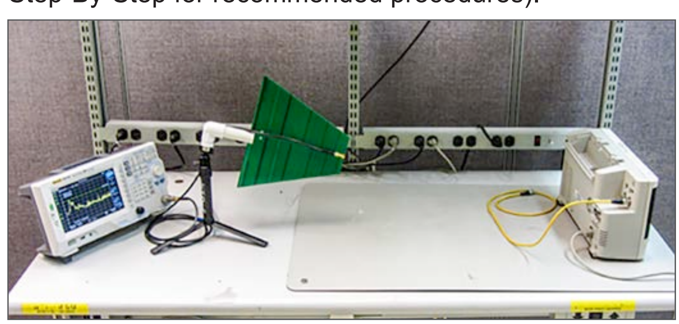


Figure 1. A typical troubleshooting test setup for radiated emissions.

Pre-compliance testing, requires a calibrated EMI antenna positioned either 1m or (better) 3m 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. Techniques for dealing with these will be described in the next article.

Figure 2. An example of a 3m 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 3V/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.

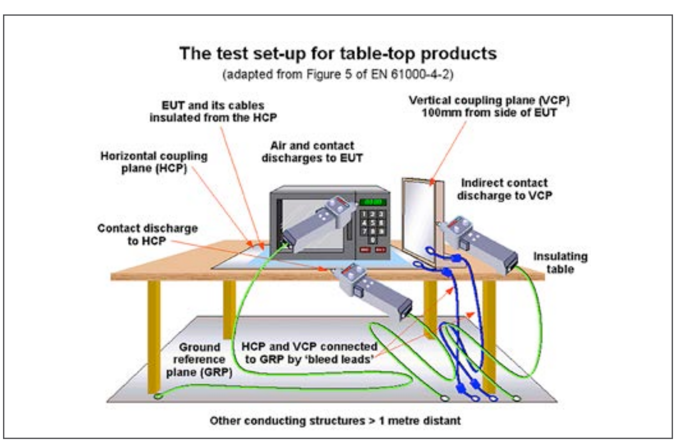


Figure 3. The ESD test setup according to IEC 6100-4-2. Image, courtesy Keith Armstrong.

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. See *Figure 3*.

Conducted Emissions

Conducted emissions testing is performed according to CISPR 11 or 22 and requires a LISN (described above) 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 3m or 10m away from the product or system under test and determining in advance whether you're passing or failing.

References

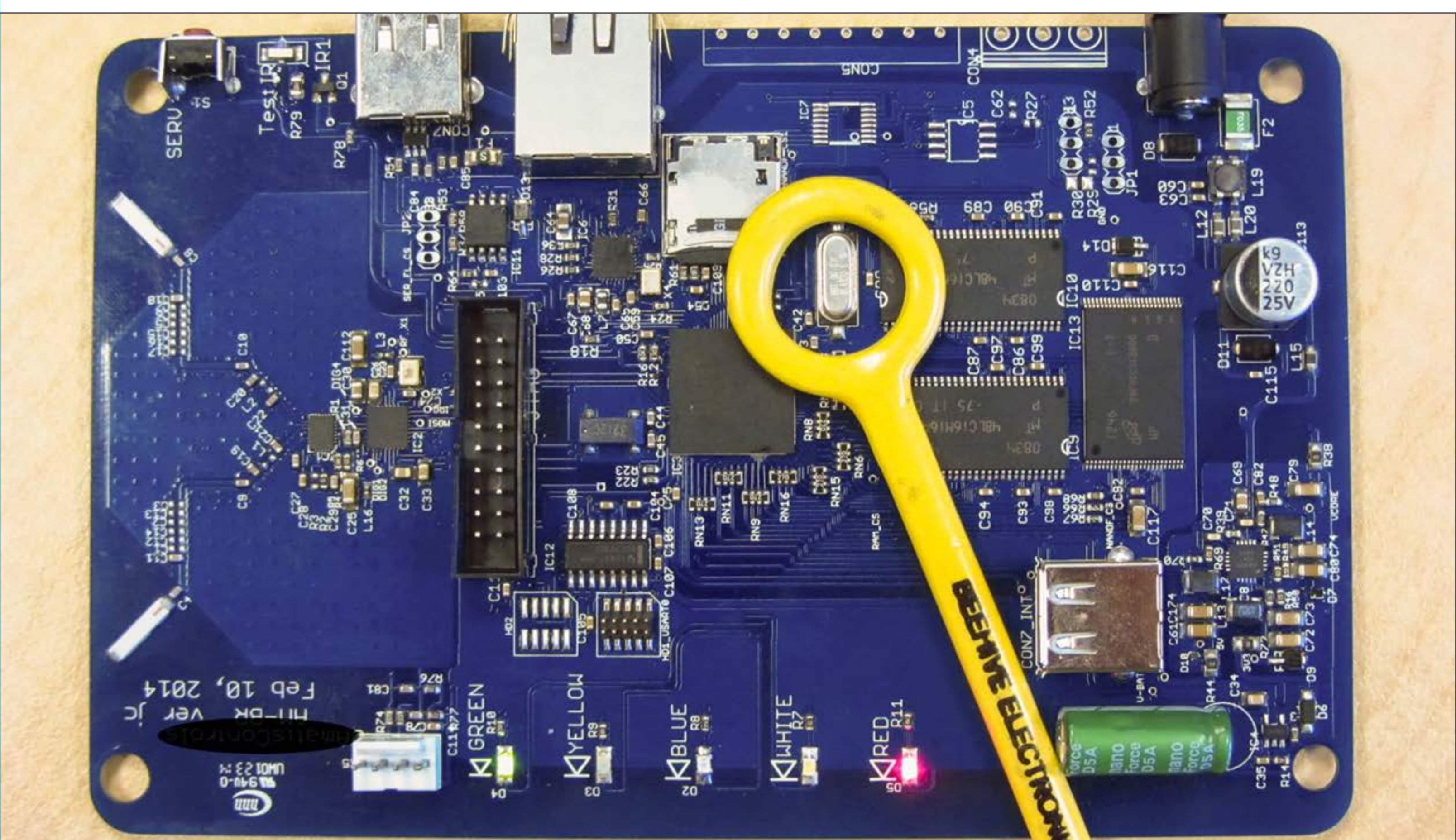
1. Real-Time Spectrum Analyzer Guide - http://learn.interferencetechnology.com/2016-real-time-spectrum-analyzer-guide/
2. List of recommended equipment - http://www.emc-seminars.com/EMI_Troubleshooting_Equipment_List-Wyatt.pdf

EMI TROUBLESHOOTING - STEP-BY-STEP

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

In this article, I'll describe the steps I usually take to troubleshoot the top four EMI issues, conducted emissions, radiated emissions, radiated immunity, and electrostatic discharge. Of these, the last three are the most prevalent issues, with radiated emissions typically being the number one failure. If your product or system (EUT) has adequate power and I/O port filtering, conducted emissions and the other power line-related immunity tests are not usually an issue.

For your convenience, I've developed a list of recommended equipment useful for troubleshooting EMI. The download link is listed in Reference 1.



EMI TROUBLESHOOTING - STEP-BY-STEP

Conducted Emissions

This is usually not an issue given adequate power line filtering, however, many low-cost power supplies lack good filtering. Some "no name" brands have no filtering at all! The conducted emissions test is easy to run, so here you go.

Set up your spectrum analyzer as follows:

1. Frequency 150 kHz to 30 MHz
2. Resolution bandwidth = 10 or 9 kHz
3. Preamp = Off
4. Adjust the Reference Level so the highest harmonics are displayed and the vertical scale is reading in even 10 dB increments
5. Use average detection initially and CISPR detection on any peaks later
6. Internal attenuation - start with 20 to 30 dB at first and adjust for best display and no analyzer overload.
7. Set the vertical units to dBµV

I also like to set the horizontal scale from linear to log, so frequencies are easier to read out.

Obtain a Line Impedance Stabilization Network (LISN) and position it between the product or system under test and the spectrum analyzer. Note the sequence of connection below!

CAUTION: It's often important to power up the EUT prior to connecting the LISN to the analyzer. This is because large transients can occur at power-up and may potentially destroy the sensitive input stage of the analyzer. Note that the TekBox LISN has built-in transient protection. Not all do…you've been warned!

Power up the EUT and then connect the 50-Ohm output port of the LISN to the analyzer. Note the harmonics are usually very high at the lower frequencies and taper off towards 30 MHz. Be sure these higher harmonics don't overdrive the analyzer. Add additional internal attenuation, if required.

By comparing the average detected peaks with the appropriate CISPR limits, you'll be able to tell whether the EUT is passing or failing prior to formal compliance testing.

Ambient Transmitters

One problem you'll run into immediately is that when testing outside of a shielded room or semi-anechoic chamber, is the number of ambient signals from sources like FM and TV broadcast transmitters, cellular telephone, and two-way radio. This is especially an issue when using current probes or external antennas. I'll usually run a baseline plot on the analyzer using "Max Hold" mode to build up a composite ambient plot. Then, I'll activate additional traces for the actual measurements. For example, I often have three plots or traces on the screen; the ambient baseline, the "before" plot, and the "after" plot with some fix applied.

Often, its easier to narrow the frequency span on the spectrum analyzer down to zero in on a particular harmonic, thus eliminating most of the ambient signals. If the harmonic is narrow band continuous wave (CW), then reducing the resolution bandwidth (RBW) can also help separate the EUT harmonics from nearby ambients. Just be sure reducing the RBW doesn't also reduce the harmonic amplitude.

Another caution is that strong nearby transmitters can affect the amplitude accuracy of the measured signals, as well as create mixing products that appear to be harmonics, but are really combinations of the transmitter frequency and mixer circuit in the analyzer. You may need to use an external bandpass filter at the desired harmonic frequency to reduce the affect of the external transmitter. Although more expensive, an EMI receiver with tuned preselection would be more useful than a normal spectrum analyzer in high RF environments. Keysight Technologies and Rohde & Schwarz would be suppliers to consider. All these techniques are described in more detail in *Reference 3*.

Radiated Emissions

This is normally the highest risk test. Set up your spectrum analyzer as follows:

1. Frequency 10 to 500 MHz
2. Resolution bandwidth = 100 or 120 kHz
3. Preamp = On (or use an external 20 dB preamp if the analyzer lacks this)
4. Adjust the Reference Level so the highest harmonics are displayed and the vertical scale is reading in even 10 dB increments
5. Use positive peak detection
6. Set the internal attenuation = zero

Sometimes I prefer setting the vertical units from the default dBm to dBµV, so the displayed numbers are positive. This is also the same unit used in the test limits of the standards. I also like to set the horizontal scale from linear to log, so frequencies are easier to read out.

I perform my initial scan up to 500 MHz, because this is usually the worst case band for digital harmonics. You'll want to also record the emissions at least up to 1 GHz (or higher) in order to characterize any other dominant emissions. Generally speaking, resolving the lower frequency harmonics will also reduce the higher harmonics.

Near Field Probing

Most near field probe kits come with both E-field and H-field probes. Deciding on H-field or E-field probes depends on whether you'll be probing currents - that is, high di/dt - (circuit traces, cables, etc.) or high voltages - that is, dV/dt - (switching power supplies, etc.) respectively. Both are useful for locating leaky seams or gaps in shielded enclosures.

Start with the larger H-field probe (*Figure 1*) and sniff around the product enclosure, circuit board(s), and attached cables. The objective is to identify major noise sources and specific narrow band and broadband frequencies. Document the locations and dominant frequencies observed. As you zero in on sources, you may wish to switch to smaller-diameter H-field probes, which will offer greater resolution (but less sensitivity).

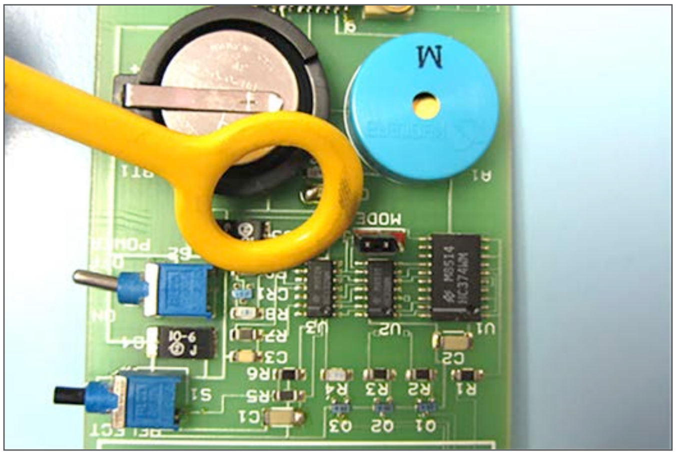


Figure 1. A near field probe is used to help identify potential sources of emissions.

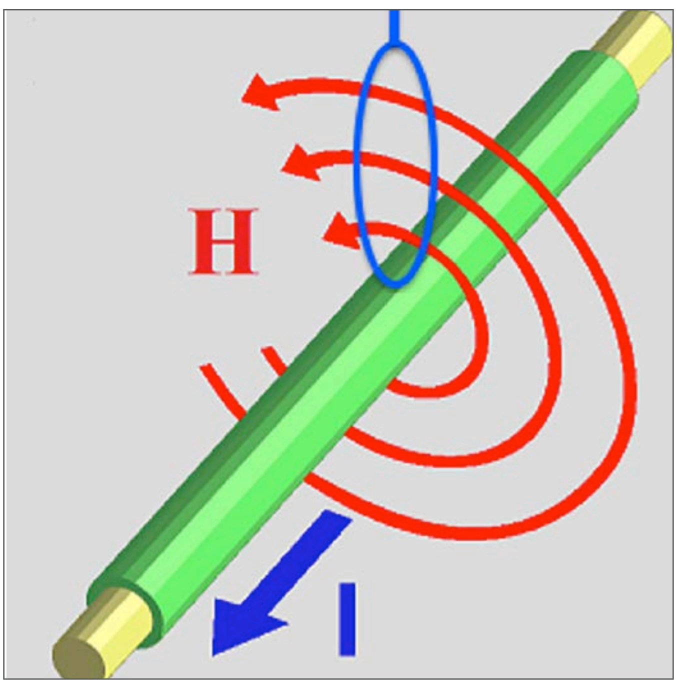


Figure 2. H-field probes offer the best sensitivity when oriented in relation to the circuit trace or cable, as shown. Figure, courtesy Patrick André.

Remember that not all sources of high frequency energy located on the board will actually radiate! Radiation requires some form of coupling to an “antenna-like” structure, such as an I/O cable, power cable, or seam in the shielded enclosure.

Compare the harmonic frequencies with known clock oscillators or other high frequency sources. It will help to use the Clock Oscillator Calculator, developed by my co-author, Patrick André. See the download link in *Reference 2*.

When applying potential fixes at the board level, be sure to tape down the near field probe to reduce the variation you’ll experience in physical location of the probe tip. Remember, we’re mainly interested in relative changes as we apply fixes.

Also, H-field probes are most sensitive (will couple the most magnetic flux) when their plane is oriented in parallel with the trace or cable. It’s also best to position the probe at 90 degrees to the plane of the PC board. See *Figure 2*.

Current Probe

Next, measure the attached common mode cable currents (including power cables) with a high frequency current probe, such as the Fischer Custom Communications model F-33-1, or equivalent (*Figure 3*). Document the locations of the top several harmonics and compare with the list determined by near field probing. These will be the most likely to actually radiate and cause test failures, because they are flowing on antenna-like structures (cables). Use the manufacturer’s supplied calibration chart of transfer impedance to calculate the actual current at a particular frequency. Note that it only takes 5 to 8 μA of high frequency current to fail the FCC or CISPR test limits.

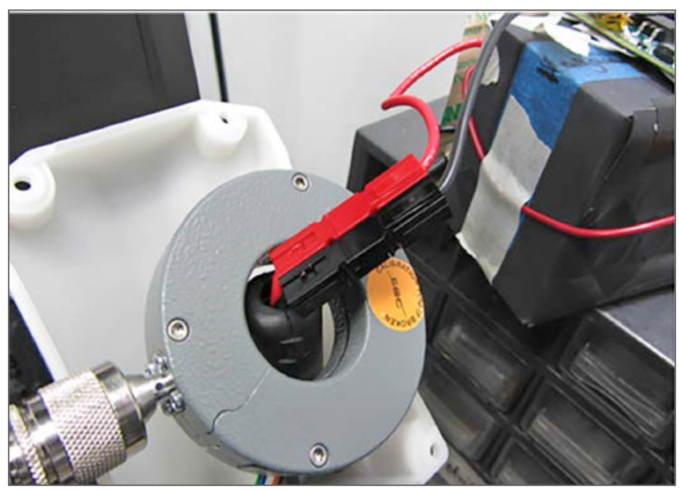


Figure 3. Use of a current probe to measure high frequency currents flowing on I/O and power cables.

It’s a good idea to slide the current probe back and forth to maximize the harmonics. This is because some frequencies will resonate in different places, due to standing waves on the cable.

Its also possible to predict the radiated E-field (V/m) given the current flowing in a wire or cable, with the assumption the length is electrically short at the frequency of concern. This has been shown to be accurate for 1m long cables at up to 200 MHz. Refer to *Reference 3* for details.

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 important thing I 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 3m or 10m away from the product or system under test and determining in advance whether you're passing or failing.

Pre-Compliance Testing for Radiated Emissions

If you're desiring to set up a pre-compliance test, (#2 above), then given a calibrated EMI antenna spaced 3m or 10m away from the EUT, you can calculate the E-field (dBμV/m) by recording the dBμV reading of the spectrum analyzer and factoring in the coax loss, external preamp gain (if used), any external attenuator (if used), and antenna factor (from the antenna calibration provided by the manufacturer). This calculation can then be compared directly with the 3m or 10m radiated emissions test limits using the formula:

E-field (dBμV/m) = SpecAnalyzer (dBμV) - PreampGain (dB) + CoaxLoss (dB) + AttenuatorLoss (dB) + AntFactor (dB)

For the purposes of this article, I'll focus mainly on the procedure for troubleshooting using a close-spaced antenna (#1 above) for general characterization of harmonic levels actually being radiated and testing potential fixes. For example, knowing you may be over the limit by 3 dB at some harmonic frequency means your goal should be to reduce that emission by 6 to 10 dB for adequate margin.

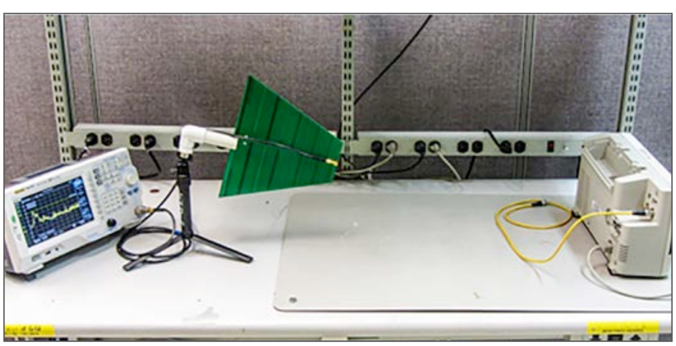


Figure 4. A typical test setup to measure actual radiated emissions while troubleshooting the causes.

Troubleshooting with a Close-Spaced Antenna

Once the product's harmonic profile is fully characterized, it's time to see which harmonics actually radiate. To do this, we use an antenna spaced at least 1m away from the product or system under test to measure the actual emissions (*Figure 4*). Typically, it will be leakage from attached I/O or power cables, as well as leakage in the shielded enclosure. Compare this data to that of the near field and current probes. Can you now determine the probable source(s) of the emissions noted?

Try to determine if cable radiation is the dominant issue by removing the cables one by one. You can also try installing a ferrite choke on one, or more, cables as a test. Use the near field probes to determine if leakage is also occurring from seams or openings in the shielded enclosure.

Once the emission sources are identified, you can use your knowledge of filtering, grounding, and shielding to mitigate the problem emissions. Try to determine the coupling path from inside the product to any outside cables. In some cases, the circuit board may need to be redesigned by optimizing the layer stack-up or by eliminating high speed traces crossing gaps in return planes, etc. By observing the results in real time with an antenna spaced some distance away, the mitigation phase should go quickly.

Common Issues

There are a number of product design areas that can cause radiated emissions:

1. Poor cable shield terminations is the top issue
2. Leaky product shielding
3. Internal cables coupling to seams or I/O areas
4. High speed traces crossing gaps in the return plane
5. Sub-optimal layer stack-up

Refer to the references for additional details on system and PC board design issues that can cause emissions failures.

Radiated Immunity

Most radiated immunity tests are performed from 80 to 1000 MHz (or, in some cases, as high as 2.7 GHz). Common test levels are 3 or 10 V/m. Military products can go as high as 50 to 200 V/m, depending on the operational environment. The commercial standard for most products is IEC 61000-4-3, whose test setup is quite involved. However, using some simple techniques, you can identify and resolve most issues quickly.

Handheld Radio

For radiated immunity, we generally start outside the EUT and use license-free handheld transmitters, such as the Family Radio Service (FRS) walkie-talkies (or equivalent) to determine areas of weakness. By holding these low power radios close to the product or system under test, you can often force a failure (*Figure 5*).

Hold the transmit button down and run the radio antenna all around the EUT. This should include all cables, seams, display ports, etc.

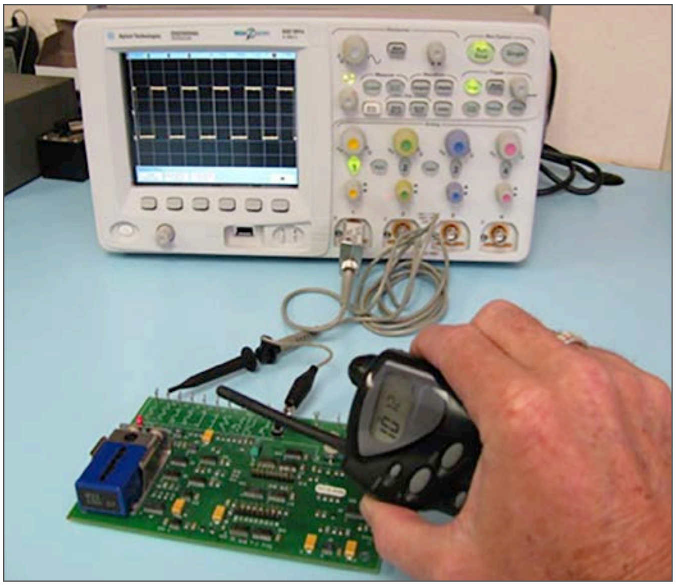


Figure 5. Using a license-free transmitter to force a failure.

RF Generator

It's very common that only certain frequency bands are susceptible and sometimes the fixed frequency hand-held radios are not effective. In that case, I use an adjustable RF generator with attached large size H-field probe and probe all around at known failing frequencies. It also helps to probe the internal cables and PC board to determine areas of sensitivity. For smaller products, as in *Figure 6*, try using the smaller H-field probes for best physical resolution.

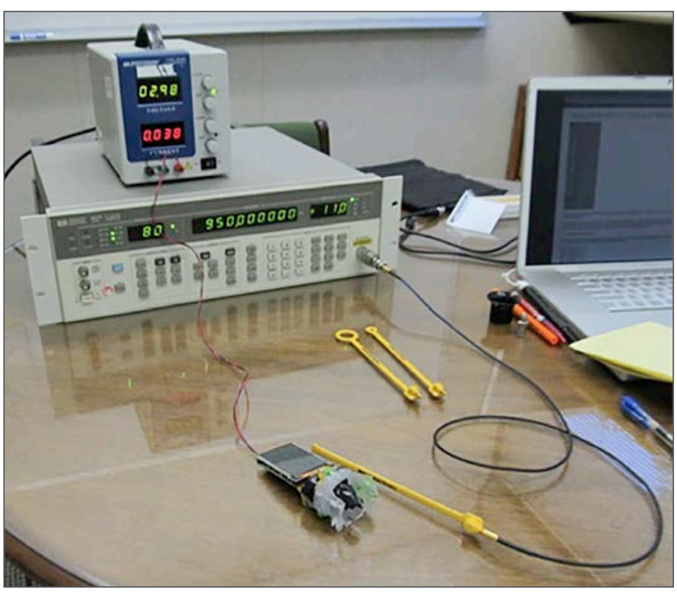


Figure 6. Using an RF generator and H-field probe to determine areas of sensitivity.

In place of the larger lab-quality RF generators, I also use a smaller USB-controlled RF synthesizer, such as the Windfreak SynthNV (or equivalent) with the near field probe. The SynthNV can produce up to +19 dBm RF power from 34 MHz to 4.4 GHz, so works well. This also fits into my EMI troubleshooting kit nicely. See Figure 7. You'll find a list of recommended generators in Reference 1.

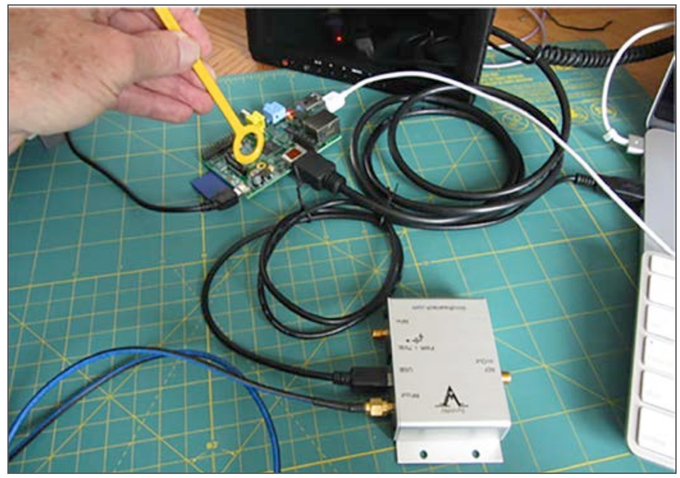


Figure 7. Using a small synthesized RF generator to produce intense RF fields around the probe tip.

Electrostatic Discharge

Electrostatic discharge testing is best performed using a test setup as described in the IEC 61000-4-2 standard. This requires a test table and ground planes of certain dimensions. The EUT is placed in the middle of the test table. I usually suggest replacing floor tiles with copper or aluminum 4 x 8-foot sheets, which will fit right into the spaces of the existing tiles (*Figure 8*).

Testing requires an ESD simulator, which is available from a number of sources. See *Reference 1*. I use the older KeyTek MiniZap, which is relatively small and can be adjusted to +/- 15 kV. There are several other suitable (and newer) designs.

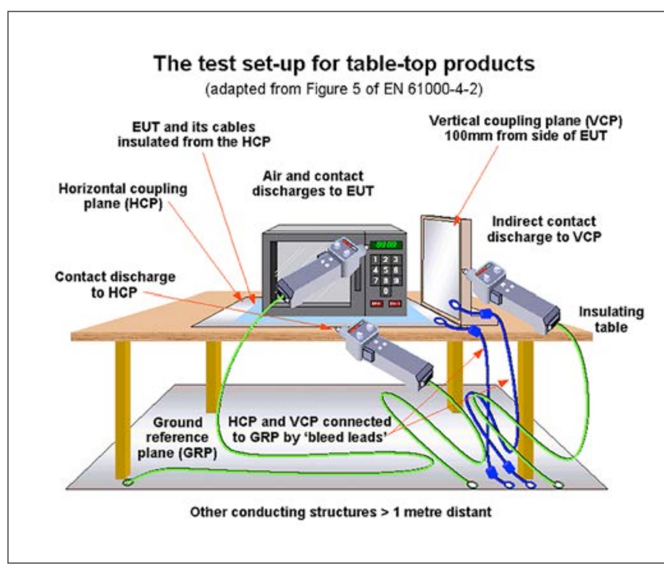


Figure 8. The ESD test setup according to IEC 6100-4-2. Image, courtesy Keith Armstrong.

ESD testing is rather complex as far as identifying the test points, but basically, there are two tests - air discharge and contact discharge. Use air discharge for all points where an operator could touch the outside of the EUT. Use contact discharge for all exposed metal where an operator could touch and discharge into. Test both positive and negative polarities. Most commercial tests require 4 kV contact discharge and 8 kV air discharge.

The test setup also includes horizontal and vertical coupling planes. Use the contact discharge tip into the coupling planes. These planes need a high-impedance discharge path to earth. See the IEC standard for details and exact test procedures.

Figure 9. A typical ESD simulator with air and contact discharge tips. It can produce up to +/- 15 kV.

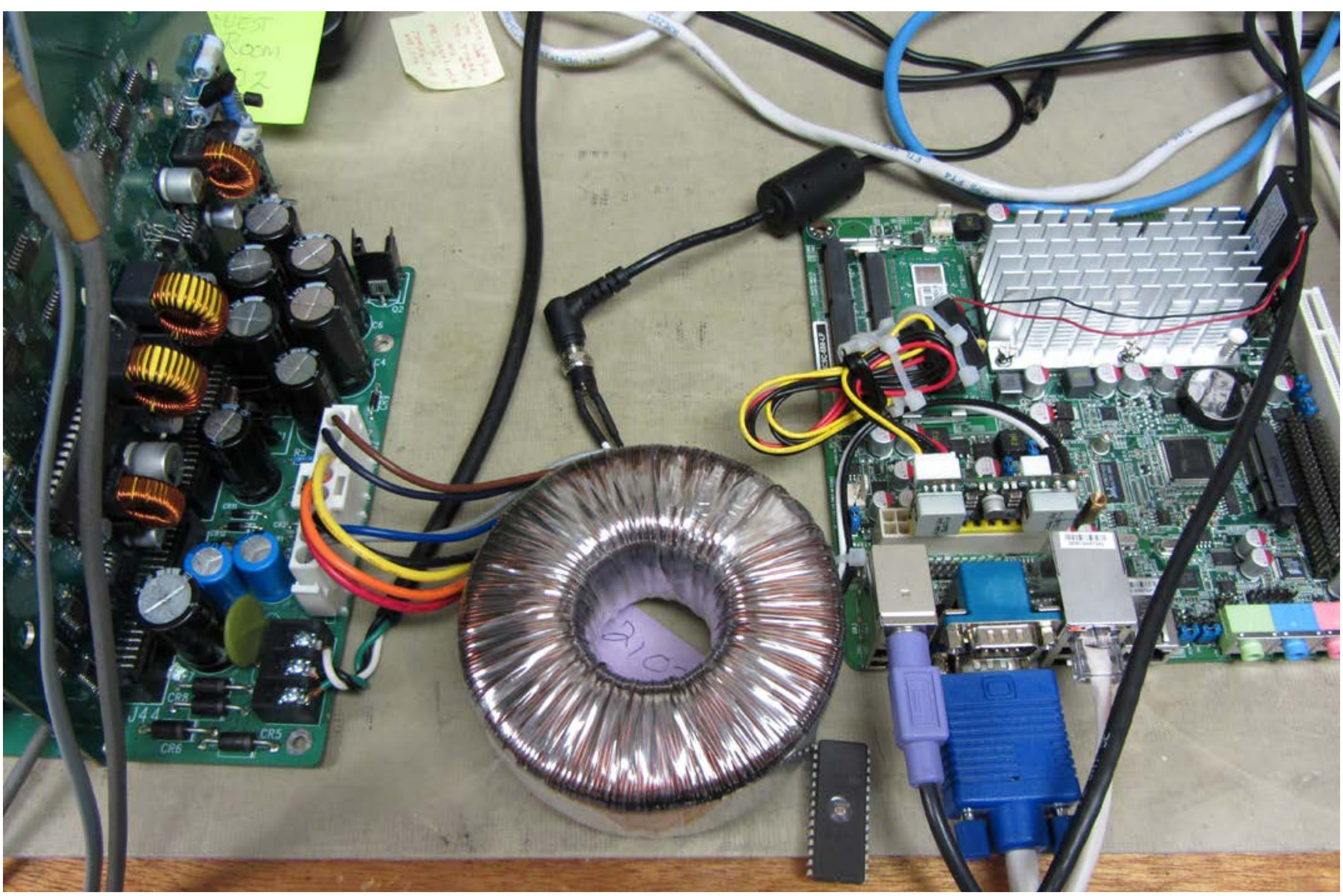
Summary

By developing your own EMI troubleshooting and pre-compliance test lab, you'll save time and money by moving the troubleshooting process in-house, rather than scheduling time and the related cost and scheduling delays by depending on commercial test labs.

Most of the high-risk EMI tests are easily performed with low-cost equipment. The cost savings by performing troubleshooting at you own facility can mount up to hundreds of thousands of dollars and weeks or months of product delays.

References

1. Recommended list of EMI troubleshooting equipment - http://www.emc-seminars.com/EMI_Troubleshooting_Equipment_List-Wyatt.pdf
1. Clock Oscillator Calculator (Patrick André) - http://andreconsulting.com/Harmonics.xls
2. André and Wyatt, EMI Troubleshooting Cookbook for Product Designers, SciTech, 2014.
3. Joffe and Lock, Grounds For Grounding, Wiley, 2010
4. Ott, Electromagnetic Compatibility Engineering, Wiley, 2009
5. Mardiguian, EMI Troubleshooting Techniques, McGraw-Hill, 2000
6. Montrose, EMC Made Simple, Montrose Compliance Services, 2014
7. Morrison, Grounding And Shielding - Circuits and Interference, Wiley, 2016
8. Williams, EMC For Product Designers, Newnes, 2017



COMMON COMMERCIAL EMC STANDARDS

Listed here are some of the more common commercial EMC standards. Most commercial products will use either CISPR 11 or CISPR 22 for radiated and conducted emissions. The series IEC 61000-4-X are very common standards for product immunity testing, such as ESD, EFT, power line surge, etc.

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 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/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 61000-1-6	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 61000-3-2	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 continued	
Document Number	Title
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/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 61000-5-6	Electromagnetic compatibility (EMC) - Part 5-6: Installation and mitigation guidelines - Mitigation of external EM influences

IEC continued	
Document Number	**Title**
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 61000-6-7	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 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 continued	
Document Number	**Title**
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

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 13	Sound and television broadcast receivers and associated equipment - Radio disturbance characteristics - Limits and methods of measurement
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 continued	
Document Number	Title
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 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 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 continued	
Document Number	Title
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
CISPR 22	Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement
CISPR 24	Information technology equipment - Immunity characteristics - Limits and methods of measurement
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

EMC & DESIGN CONFERENCES

EMC & DESIGN CONFERENCES

Applied Power Electronics (APEC)
March 26-30, 2017
Tampa, Florida
http://www.apec-conf.org

APEC focuses on the practical and applied aspects of the power electronics business. This is not just a designer's conference; APEC has something of interest for anyone involved in power electronics:

- Equipment OEMs that use power supplies and dc-dc converters in their equipment
- Designers of power supplies, dc-dc converters, motor drives, uninterruptable power supplies, inverters and any other power electronic circuits, equipment and systems
- Compliance engineers testing and qualifying power electronics equipment or equipment that uses power electronics

The Battery Show - Europe
April 4-6, 2017
Stuttgart, Germany
https://www.thebatteryshow.com

The Battery Show Europe Exhibition & Conference is a showcase of advanced battery manufacturing and technology for electric & hybrid vehicles, utility & renewable energy support, portable electronics, medical technology, military and telecommunications.

The Battery Show
September 12-14, 2017
Novi, MI
https://www.thebatteryshow.com

The Battery Show 2017 is the premier showcase of the latest advanced battery technology.

Automotive Test Expo
October 24-26, 2017
Novi, MI
http://www.testing-expo.com/usa/

This conference includes the very latest technologies and services that are designed to ensure that the highest standards are met in terms of product quality, reliability, durability and safety.

International Exhibition with Workshops on Electromagnetic Compatibility EMC (EMV 2017)
March 28-30, 2017
Stuttgart, Germany
https://www.mesago.de/en/EMV/home.htm?ovs_tnid=0

EMV is Europe's leading event on electromagnetic compatibility. Meet the industry's leading companies for EMC-equipment, components and EMC-services. The event offers a wide range of EMC-specific topics. The perfect platform to get the latest information on newest trends and developments!

The 2017 Symposium on EMC+SIPI
August 7-11, 2017
National Harbor, Maryland
http://www.emc2017.emcss.org

The 2017 Symposium on EMC+SIPI is the leading event to provide education of EMC and Signal and Power Integrity techniques to specialty engineers. The Symposium features five full days of innovative sessions, interactive workshops, tutorials, experiments, demonstrations, and social networking events.

USEFUL PRE-COMPLIANCE REFERENCES
(GROUPS, BOOKS, ARTICLES, & WHITE PAPERS)

LINKEDIN GROUPS

EMC Troubleshooters
EMC Experts
EMC Testing and Compliance
Electromagnetic Compatibility Forum
ESD Experts

RECOMMENDED BOOKS

EMI Troubleshooting Cookbook for Product Designers
André and Wyatt
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 the common EMC test failures.

Grounds For Grounding
Joffe and Lock
Wiley, 2010.
This huge book includes way more topics on product design than the title suggests.

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

EMI Troubleshooting Techniques
Mardiguian
McGraw-Hill, 2000.
Good coverage of EMI troubleshooting.
Montrose, EMC Made Simple, Montrose Compliance Services, 2014. Content includes several important areas of EMC theory and product design.

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

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

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

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

LINKS TO ADDITIONAL ARTICLES AND DESIGN GUIDES

Recommended list of EMI troubleshooting equipment
http://www.emc-seminars.com/EMI_Troubleshooting_Equipment_List-Wyatt.pdf

Clock Oscillator Calculator (Patrick André)
http://andreconsulting.com/Harmonics.xls

Real-Time Spectrum Analyzer Guide
http://learn.interferencetechnology.com/2016-real-time-spectrum-analyzer-guide/

2016 EMC Filters Guide
http://learn.interferencetechnology.com/2016-emc-filters-guide/

2016 EMI Shielding Guide
http://learn.interferencetechnology.com/2016-emi-shielding-guide/

Assembling A Low-Cost EMI Troubleshooting Kit Part 1 (Radiated Emissions)
https://interferencetechnology.com/assembling-low-cost-emi-troubleshooting-kit-part-1-radiated-emissions/

Assembling A Low-Cost EMI Troubleshooting Kit Part 2 (Immunity)
https://interferencetechnology.com/assembling-low-cost-emi-troubleshooting-kit-part-2-immunity/

The HF Current Probe: Theory and Application
https://interferencetechnology.com/the-hf-current-probe-theory-and-application/

Inexpensive Radiated Immunity Pre-Compliance Testing
https://interferencetechnology.com/inexpensive-radiated-immunity-pre-compliance-testing/

USEFUL PRE-COMPLIANCE REFERENCES
(GROUPS, BOOKS, ARTICLES, & WHITE PAPERS) CONTINUED

LINKS TO MANUFACTURER'S WHITE PAPERS

1. EMI Debugging With RTO and RTE Oscilloscopes (Rohde & Schwarz) - https://cdn.rohde-schwarz.com/pws/dl_downloads/dl_application/application_notes/1td05/1TD05-11e_-_EMI_Debugging_with_the_RS_RTO_and_RS_RTE_Oscilloscopes.pdf
2. Video / EMI Debugging With RTO and RTE Oscilloscopes (Rohde & Schwarz) - https://www.rohde-schwarz.com/us/products/test-measurement/oscilloscopes/application-videos/emi-debugging_230708.html
3. Fast and Efficient EMI Debugging with Oscilloscopes (Rohde & Schwarz) - https://cdn.rohde-schwarz.com/pws/dl_downloads/dl_common_library/dl_news_from_rs/211/NEWS_211_RTO_RTE_EMV_english.pdf
4. Low Cost EMI Pre-Compliance Testing Using a Spectrum Analyzer (Tektronix) - http://www.tek.com/document/application-note/low-cost-emi-pre-compliance-testing-using-spectrum-analyzer
5. Practical EMI Troubleshooting (Tektronix) - http://www.tek.com/document/application-note/practical-emi-troubleshooting
6. Real-Time Spectral Analysis for EMI Diagnostics (Tektronix) - http://www.tek.com/fact-sheet/real-time-spectrum-analysis-emi-diagnostics
7. EMC/EMI Pre-Compliance Testing (Signal Hound) - https://signalhound.com/applications/emc-emi-pre-compliance-testing/
8. Several EMC/EMI-related application notes (Keysight) - http://www.keysight.com/main/facet.jspx?&cc=US&lc=eng&k=EMI+troubleshooting&pSearch=tnmSearch&hasLuckySearch=true
9. EMC Pre-Compliance Measurements (Rigol) - https://rigol.desk.com/customer/en/portal/articles/2281961-emc-precompliance-measurements
10. Pre-Compliance: Using Near Field Probes (Rigol) - https://rigol.desk.com/customer/en/portal/articles/2285032-emc-precompliance-near-field-probes
11. Pre-Compliance: Susceptibility Testing (Rigol) - https://rigol.desk.com/customer/en/portal/articles/2285036-precompliance-susceptibility-testing
12. Electromagnetic Compliance: Troubleshooting with Near Field probes (Siglent) - http://www.siglentamerica.com/USA_website_2014/FAQ/SSA/PrecomplianceNearField.pdf
13. Electromagnetic Compliance: Pre-Compliance Conducted Emissions testing (Siglent) - Electromagnetic Compliance: Troubleshooting with Near Field probes (Siglent) - http://www.siglentamerica.com/USA_website_2014/FAQ/SSA/PrecomplianceConducted_092016.pdf
14. Electromagnetic Compliance: Pre-Compliance Test Basics (Siglent) - http://siglentamerica.com/Uploadfile/file/20160923/PrecomplianceBasics_082016.pdf

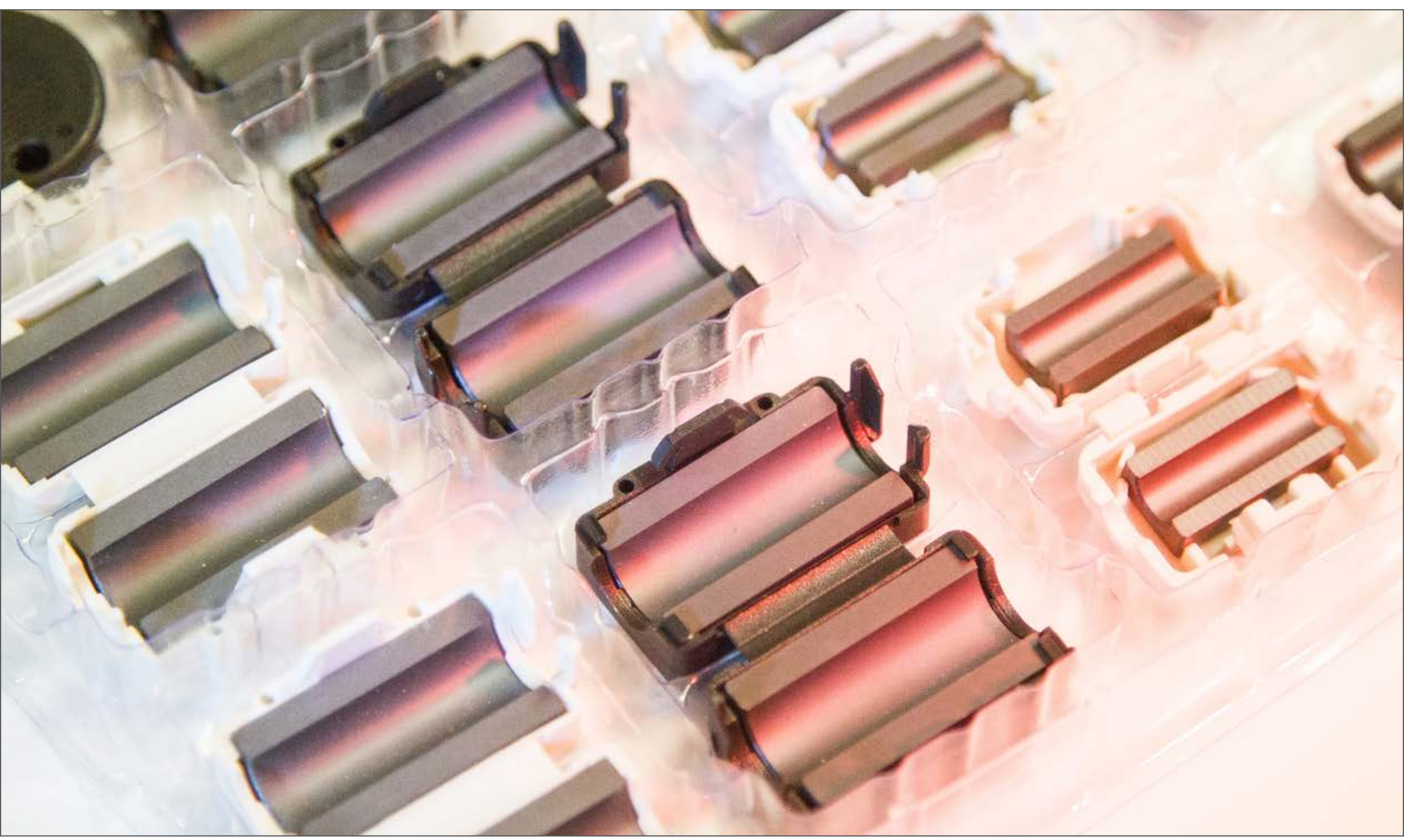
SUMMARY

Hopefully, this guide to EMC troubleshooting and pre-compliance testing will be helpful for your current and future product designs. Issues like poor shielding, poorly terminated cable shields, and sub-optimal PC board design and layout can cause numerous EMC/EMI failures. As EMC consultants, running into these issues consistently with clients is one reason why my co-author, Patrick André, and I wrote our book, EMI Troubleshooting Cookbook For Product Designers.

Many of these design issues can be resolved by knowing simple filtering, grounding, and bonding principles, which you can learn from the included book list.

By developing your own in-house EMC test and troubleshooting lab, as well as learning the skills in tracking down EMC test failures using a methodical science-based process, you will save your company weeks of time and many thousands of dollars.

Still to come in 2017 will be free downloadable EMC guides on EMC Measurements and Product Design For EMC Compliance. Between this guide and the other two under development, you should have a handy collection of product design guidance and reference information to ward off the most common EMC-related issues.



INDEX OF ADVERTISERS

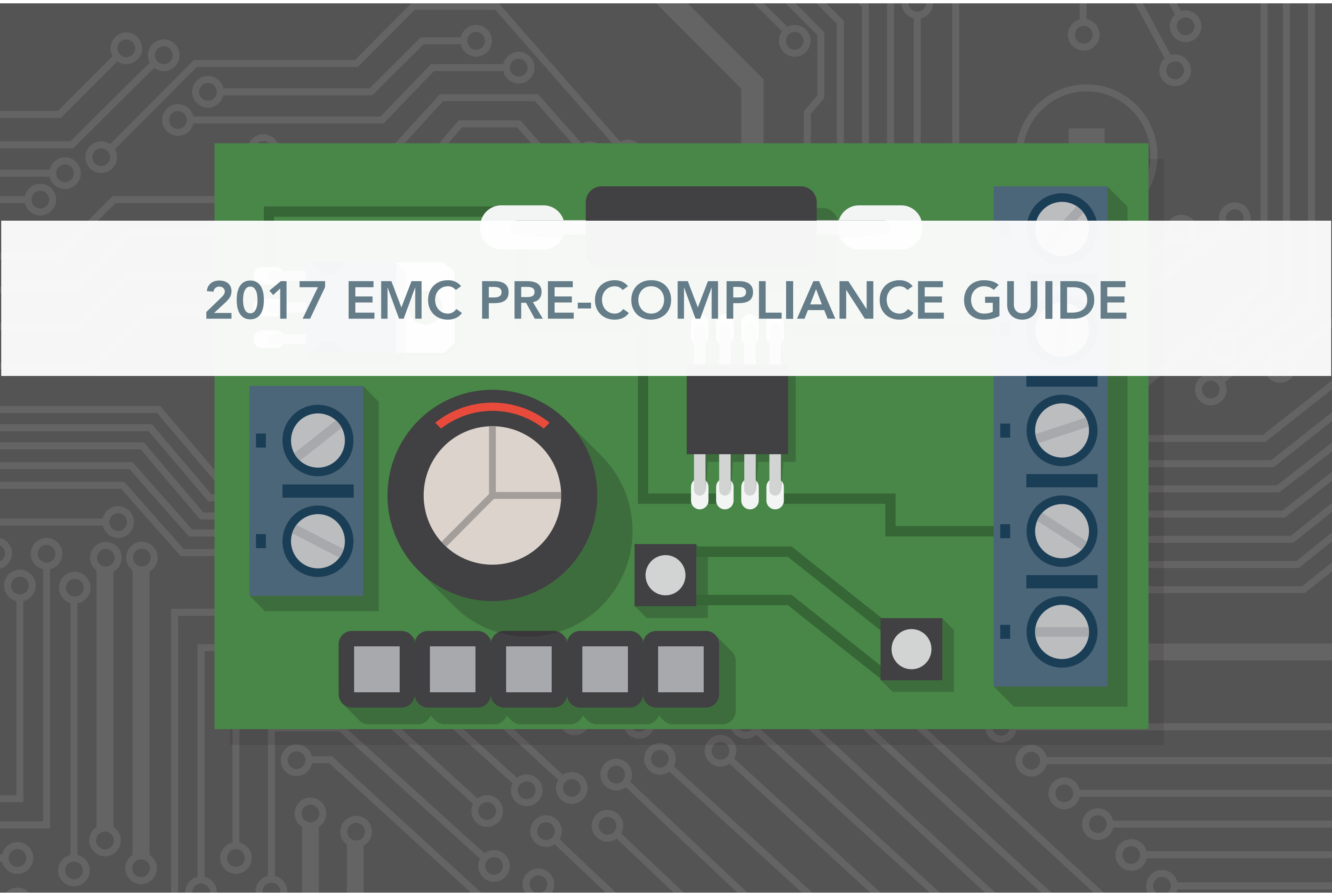
EMC LIVE 2017
Online Event
April 25-27, 2017

t: (484) 688.0300
e: info@interferencetechnology.com
w: emc.live
page: 6

2017 IEEE EMC+SIPI SYMPOSIUM ONLINE
Online Event
August 7-11, 2017

e: emc2017online@ltem.media
w: www.emc2017online.emcss.org
page: 10

2017 EMC PRE-COMPLIANCE GUIDE



INTERFERENCE TECHNOLOGY

INTERFERENCE TECHNOLOGY GUIDE SERIES
www.interferencetechnology.com