

Wyatt Technical Services, LLC

EMC Seminars & Design

Bench Top Troubleshooting the Top Three EMC Issues

Presented by: Kenneth Wyatt

Contact via: www.emc-seminars.com

Bench top troubleshooting

This presentation will describe how I troubleshoot the top three EMC issues; radiated emissions, radiated immunity and ESD right on my work bench.

I'll also briefly take you on a tour of my new book, *Create Your Own EMC Troubleshooting Kit (Volume 1)*, which describes some affordable equipment, tools and probes for characterizing and troubleshooting the most common EMC issues right on your workbench.



Presenter Bio



Kenneth Wyatt is principal consultant of Wyatt Technical Services LLC, as well as past senior technical editor for *Interference Technology Magazine* (2016 to 2018). He is based in Colorado and has worked in the field of EMC engineering for over 30 years with a specialty is EMI troubleshooting and pre-compliance testing. He trains and speaks internationally, is widely published, and is the co-author of the popular *EMI Troubleshooting Cookbook for Product Designers and released Create Your Own EMC Troubleshooting Kit (Volume 1)*, October 2020. He may be contacted through his web site, <http://www.emc-seminars.com>.

Radiated Emissions Troubleshooting

Why do products radiate?

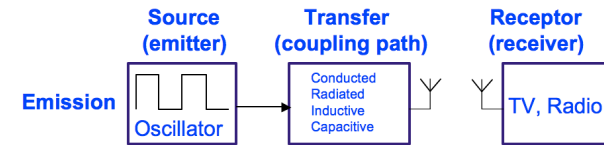


▪ **Energy** + Coupling Path + **Antenna** = Radiated Emissions

▪ *Take away any of the three elements and no RE...*

- ✓ No energy >>> No RE
- ✓ No coupling path >>> No RE
- ✓ No antenna >>> No RE

Assessing radiated emissions



For **Radiated Emissions** we want to find:

1. EMI Source - Is it a periodic or transient signal with dv/dt and di/dt ?
2. Path - What is the path to connect the EMI source to the Receptor?
3. Antenna - Are there cables, portions of PCBs, metal enclosures that can couple?

Ref: Lee Hill

The four coupling paths

Energy Source → Victim Circuit

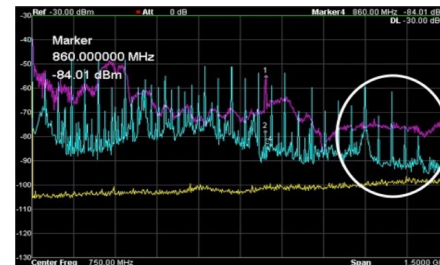
The four possible coupling paths

	Must have this electrical thing	Must have this physical thing
1. Conducted	i and shared R	2 conductors
2. Radiated	di/dt	2 antennas
3. Capacitive	dV/dt	2 surfaces
4. Inductive	di/dt	2 loops

ALL noise coupling problems MUST be one of these four, or a combination of at most three.

Ref: Lee Hill

Narrow band versus broadband emissions



Broadband (DC-DC, addr/data)

Narrow band (clocks)

Ambient (yellow)

According to most commercial EMC standards, the normal resolution bandwidth (RBW) for 30 to 1000 MHz should be set to 120 kHz (100 kHz may also be used for troubleshooting purposes).

Clock harmonic analyzer

Clock Oscillator Harmonic Analyzer					
To determine the harmonics of a specific crystal oscillator: Enter the oscillator frequency in the box and find the harmonics in the first column.					
To determine the crystal oscillator frequency for a specific harmonic: Enter the harmonic frequency in the box and find the possible oscillator frequency in the second column.					
Enter Frequency -> (MHz):	780	Harmonics of osc. Frequency (MHz)	Possible crystal oscillator frequencies for harmonic (MHz)		
		1	780.000	780.000	
		2	1560.000	390.000	
		3	2340.000	260.000	
		4	3120.000	195.000	
		5	3900.000	156.000	
		6	4680.000	130.000	
		7	5460.000	111.429	
		8	6240.000	97.500	
		9	7020.000	86.667	
		10	7800.000	78.000	
		11	8580.000	70.909	
		12	9360.000	65.000	
		13	10140.000	60.000	
		14	10920.000	55.714	
		15	11700.000	52.000	
		16	12480.000	48.750	
		17	13260.000	45.862	
		18	14040.000	43.333	

Download here: <http://www.emc-seminars.com/Harmonics.xls>

Source: Patrick André, <https://andreconsulting.com>

Troubleshooting radiated emissions – a 3 step process

Ken's 3-step troubleshooting process:

1. Use near field probes to identify energy sources and harmonics
2. Use current probes to identify harmonic currents on cables
3. Set up a nearby antenna to confirm actual emissions from EUT

Download the FREE 2017 EMC Pre-Compliance Test Guide:

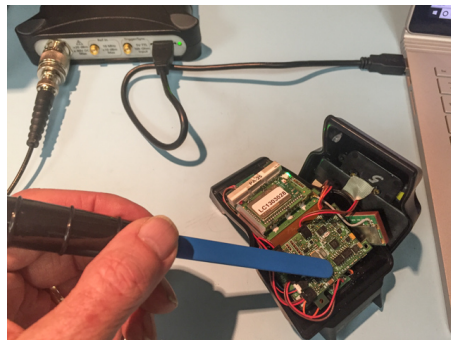
<http://learn.interferencetechnology.com/2017-emc-pre-compliance-test-guide/>



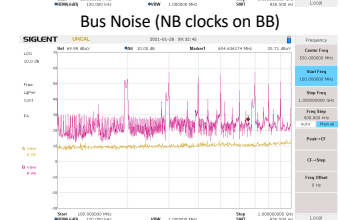
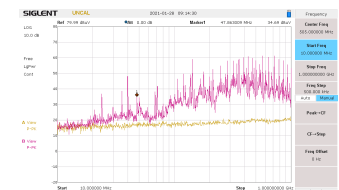
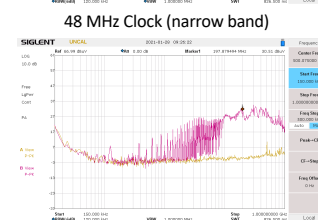
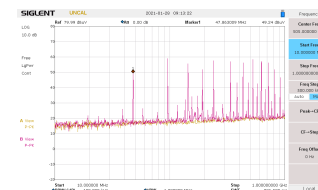
Step 1 – Identify energy sources with near field probes

While probing with the near field probes, I identify energy sources and their harmonic frequencies and levels.

Remember, not all energy sources couple to antenna-like structures!



Step 1 – Identify & document energy sources

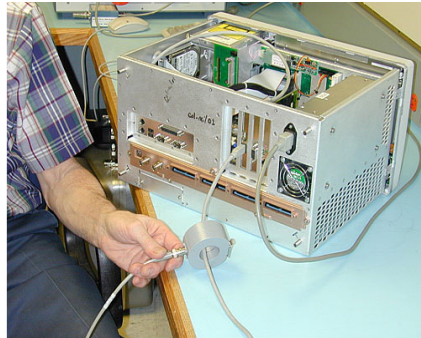


Step 2 – Characterize cables with current probes

I/O cables are well-known for radiating common-mode currents.

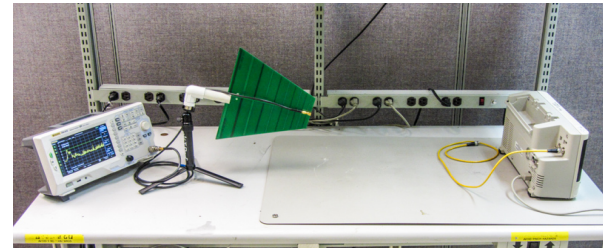
Clamp the probe around the cable under test and move it back and forth to maximize the readings (standing waves).

When troubleshooting, tape them down to the table to eliminate variables due to positioning while various fixes can be implemented to reduce the measured currents.



<https://interferencetechnology.com/the-hf-current-probe-theory-and-application/>

Step 3 – Characterize actual radiated harmonics



Now that you know the actual emissions, compare with near field and current probe data to help identify the source or sources and potential coupling paths.

Ref: <http://edn.com/electronics-blogs/the-emc-blog/4430335/Troubleshooting-EMI-on-your-bench-top>

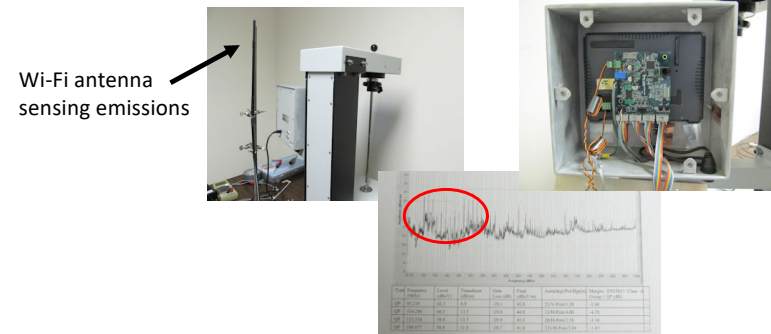
Typical design issues

Most radiated emissions problems are due to:

1. Wrong PC board stack-up (signal/power layers must have solid adjacent return plane layer)
2. Fast di/dt traces crossing gaps in the return plane
3. Lack of common mode filtering (I/O and power cables)
4. Incorrect cable shield termination
5. Poor routing of interior system cables (near-field coupling)
6. Split analog and digital ground return planes (same layer)
7. I/O connectors on opposite ends of the board

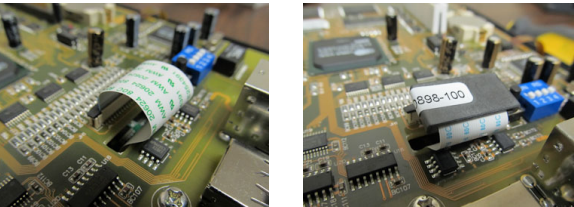
Mitigations: bonding, shielding, use of ferrite chokes, etc.

Case Study: Industrial controller



Radiated emissions failures at 95, 114, 133, 196 MHz.

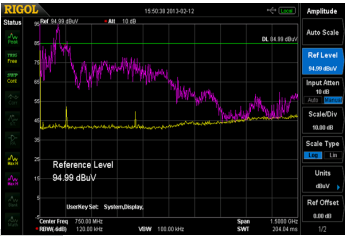
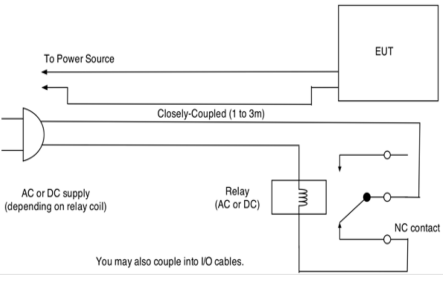
Case Study: Industrial controller



The LCD driver and poor bonding of the display to chassis was the source of emissions / edge speeds slowed down with ferrite choke.

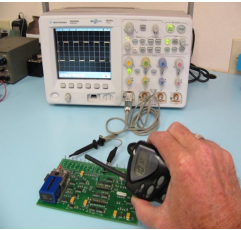
Radiated Immunity Troubleshooting

Chattering relay



A chattering relay may be easily constructed from a heavy-duty relay. By coupling the power cable to the product under test, a strong broadband field will be produced. **Be sure to insulate the relay contacts if using line voltage.**

License-free 2-way radios



Calculating E-field from Pout

$$V/m = \sqrt{\frac{30 * Pout * Gain_{Numerical}}{meters}}$$

Pout (W)	V/m at 1m	V/m at 3m	V/m at 10m
1	5.5	1.8	0.6
5	12.3	4.1	1.2
10	17.4	5.8	1.7
25	27.5	9.2	2.8
50	38.9	13.0	3.9
100	55.0	18.3	5.5
1000	173.9	58.0	17.4

Chart of calculated E-fields in V/m (assuming antenna gain = 1)

RF synthesizer with AM/pulse modulation



Using the Windfreak Technologies "SynthNV" RF synthesizer with 80% AM modulation to test radiated immunity.

RF vector gen with AM/pulse/dig modulation



Here's a PC-controlled vector signal generator from Signal Hound. This one tunes from 100 to 2500 MHz, is adjustable from -40 to +10 dBm, and also includes multiple modulations, including digital, for just \$525.

Available from: Signal Hound, www.signalhound.com. See the review article here: <http://www.edn.com/electronics-blogs/the-emc-blog/4439988/Review-Signal-Hound-VSG25A-vector-signal-generator>

RF amplifier with AM/pulse modulation

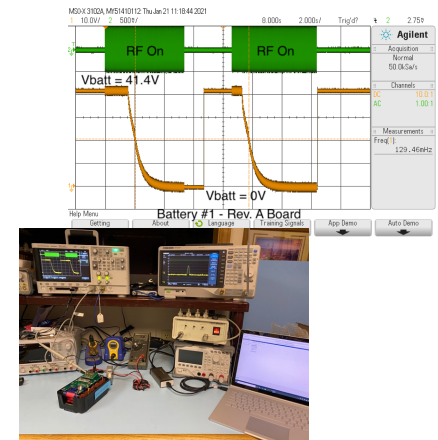
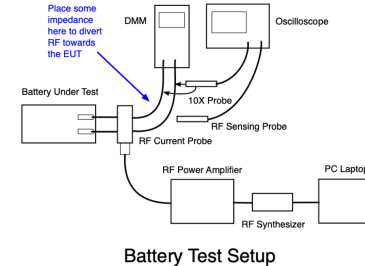
- TBDA1: 40 to 3000 MHz, +22 dBm, \$169
- TBDA2: 1.5 to 3000 MHz, +20 dBm, \$189
- TBMA3: 10 to 1000 MHz, +30 to +45 dBm, \$869



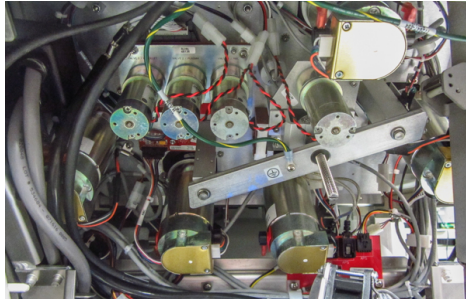
New Tekbox modulated RF broadband amplifiers can create CW, AM, & pulse at 1 kHz or 217 Hz when driven from tracking generator or other RF source.

Case Study #1 – Using CI test for RI T/S

Battery monitoring system was "disconnecting" battery supply during RI test at 100 and 127 MHz for a 20 V/m test level. After injecting RF into H-field probe, energy was determined to be coupling via the battery cables, so simulated RI test by coupling RF to battery cables. A 0.01uF capacitor was required to resolve.

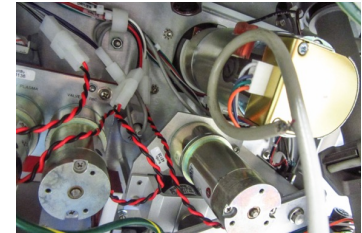
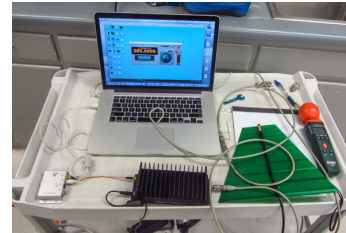


Case Study #2 – Blood analyzer



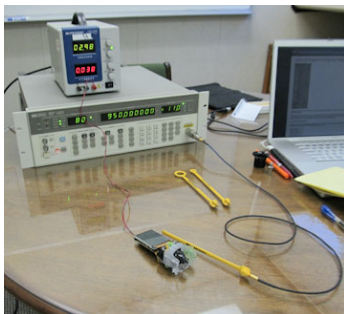
There were several pump motors in the system; two of which would increase from 10 to 10,000 rpm when RF was applied! There were multiple boards and numerous cables. Ferrites, shielding and chassis bonding had been tried without success.

Case Study #2 – Blood analyzer



I set up my immunity test system comprised of a laptop controller, RF synthesizer, driving a three-watt broadband amplifier. I tried using a small antenna to direct some RF energy into different sections without success. However, when I attached a large H-field loop (right hand picture), I was able to duplicate the issue with the two motors in question.

Case Study #3 - Blood glucose meter



The only sensitive cable!

Helped client set up radiated susceptibility simulation with RF signal generator driving an H-field probe. Using the smallest loop probe determined the most sensitive flex cables.

ESD Troubleshooting

ESD event “detector”

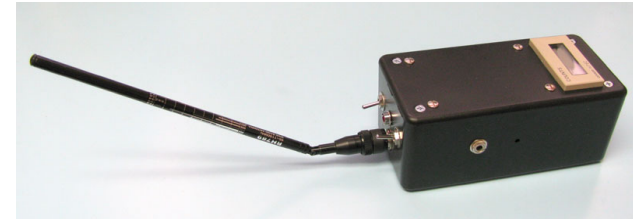
Grundig “Mini 400” shown

Receives AM/FM/SW



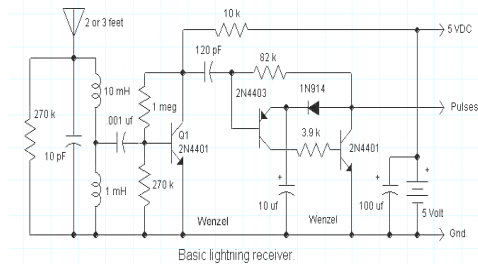
An inexpensive portable AM radio tuned “off-station” can detect ESD events from a long distance away. You should hear the “clicks” through the static. This is useful for troubleshooting and correlating potential ESD issues.

DIY ESD detector



The ESD detector I made, includes a beeper (with silencing switch), flashing LED light, and LCD event counter. These accessories can be added with additional switch transistors. See the schematic, next slide. A telescoping antenna picks up the ESD energy.

ESD event detector



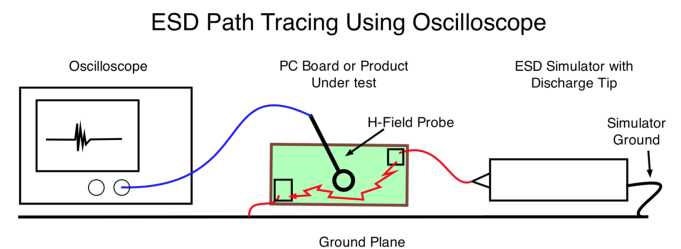
Basic homemade ESD detector circuit. Additional circuitry can be added to the negative-going pulse output for LEDs, beepers, counters, etc.

Ref: <http://www.techlib.com/electronics/lightning.html> (reprinted with permission)

Tracing the path of ESD

Often, the precise path of ESD is unknown, as is the circuit component that is being affected and causing the system failure.

By injecting a “small” (100 to 500V) pulse into the sensitive node under test, the path of ESD current may be determined by probing with an H-field probe and observing the size of the response on the oscilloscope.



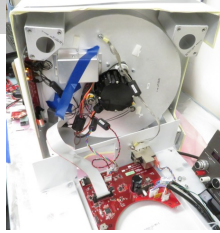
Tek Ap-Note: <https://in.tek.com/document/application-note/troubleshooting-esd-failures-using-an-oscilloscope>

Case Study – Tracing ESD (with HP 547A)

Medical-rated centrifuge cover was opening during operation during low-level ESD testing.

Traced the path using an HP 547A current tracer probe.

Was able to determine ESD was crossing through the control IC. Proper PC board bonding to chassis and two ferrite chokes resolved.



<https://www.edn.com/trace-esd-current-paths-with-the-hp-547a/>

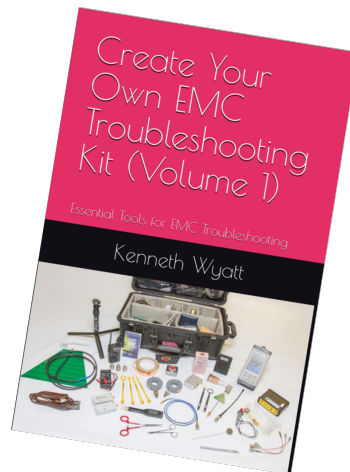
New troubleshooting book

Recently-published book

I'll also briefly take you on a quick tour of my new book, *Create Your Own EMC Troubleshooting Kit (Volume 1)*, which describes some affordable equipment, tools and probes for characterizing and troubleshooting the most common EMC issues right on your workbench.

My objective in writing this upcoming "trilogy" is to help companies develop their own in-house EMC troubleshooting capability to at least some intermediate level, using low-cost tools and tricks I've developed over my 30 years experience.

<https://www.amazon.com/dp/B08LGNFPC2#ace-9165775916>

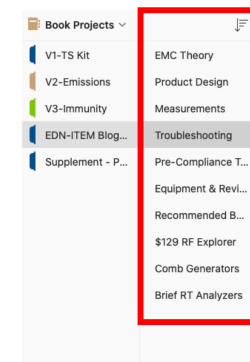


Compilation and reorganization from my blogs

I use MS OneNote to create most of my content for blogs and articles

Permission granted to republish and organize blogs

Sorted blogs into categories, then organized into chapters



Troubleshooting				
Monday, March 16, 2020 4:36 PM				
15 x 4 = 60 pgs				
6/1/12	An EMC troubleshooting kit - part 1a (emissions)	9	Testing	Discussion of troubleshooting accessories for radiated emissions
6/1/12	An EMC troubleshooting kit - part 1b (emissions)	3	Testing	Discussion of troubleshooting accessories for radiated emissions
6/20/12	An EMC troubleshooting kit - part 2 (ESD immunity)	3	Testing	Discussion of troubleshooting accessories for ESD immunity

Started separate chapters in Word

Created content using MS OneNote then ported each chapter to MS Word.

This made it easier for the technical reviewers.

Then, assembled all the content and created a PDF to submit to Amazon's KDP publishing.

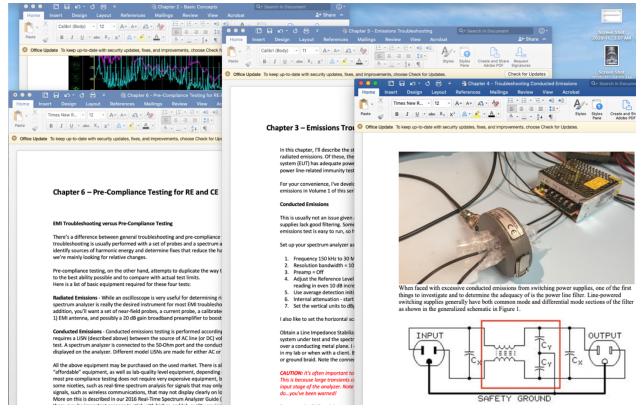


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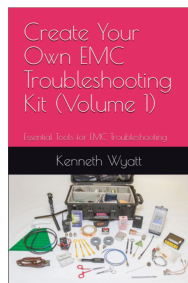
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Publishing Plan

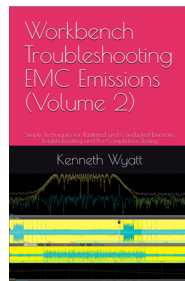
Volume 1 – Creating your kit of tools

Volume 2 – radiated and conducted emissions

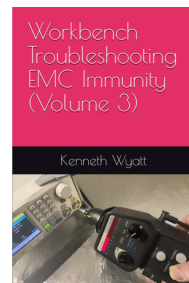
Volume 3 – radiated/conducted immunity, EFT, ESD



October 2020



February 2021



April 2021

Suggested references

- André and Wyatt, EMI Troubleshooting Cookbook for Product Designers, SciTech Publishing (2014)
- Wyatt, The Top Five Reasons Products Fail EMI Testing (Interference Technology), <https://interferencetechnology.com/the-top-five-reasons-products-fail-emi-testing/>
- Wyatt, EMI Troubleshooting – Step-By-Step (Interference Technology), <https://interferencetechnology.com/emi-troubleshooting-step-step/>
- Wyatt, EMC Troubleshooting Kit – part 4 (Radiated Immunity) (EDN), <https://www.edn.com/an-emc-troubleshooting-kit-part-4-radiated-immunity/>
- Wyatt, Tracing the path of ESD Current (EDN), <https://www.edn.com/trace-esd-current-paths-with-the-hp-547a/>
- Wyatt, Create Your Own EMC Troubleshooting Kit – Volume 1, <https://www.amazon.com/dp/B08LGNFPC2#ace-9165775916>
- Wyatt, The EMC Blog at www.EDN.com, www.InterferenceTechnology.com and www.design-4-EMC.com

Questions?



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