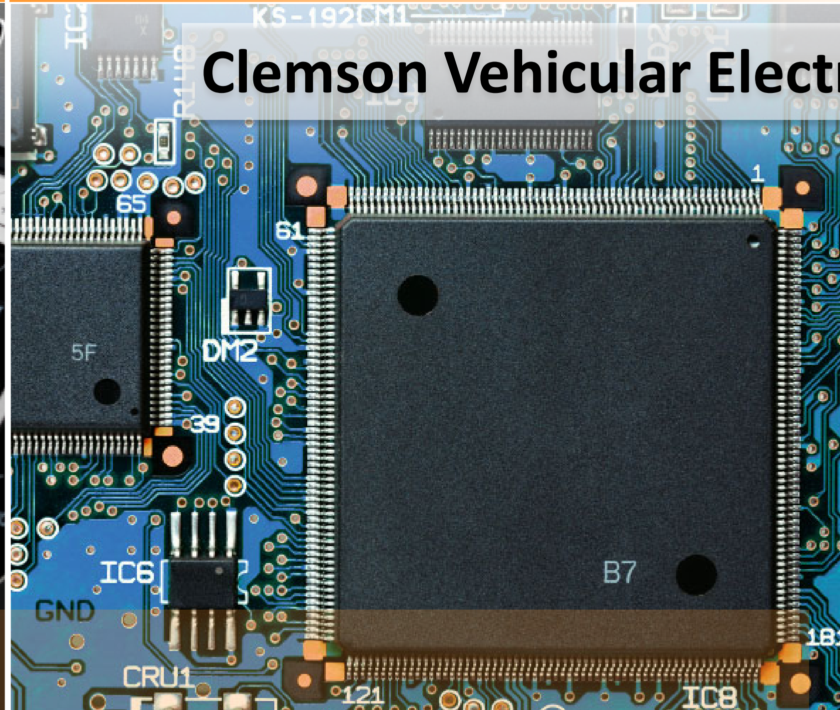


Clemson Vehicular Electronics Laboratory

Reliable Automotive Electronics

April 29, 2013

Design for Guaranteed EMC Compliance

Todd Hubing
Clemson University

CLEMSON UNIVERSITY INTERNATIONAL CENTER FOR AUTOMOTIVE RESEARCH

EMC Requirements and Key Design Considerations

Radiated Emissions

- 1 HF GND
- Risetime Control
- Filtered I/O
- Adequate Decoupling
- Balance Control

Radiated Susceptibility

- 1 HF GND
- Filtered I/O
- Adequate Decoupling
- Balance Control

Transient Immunity

- LF Current Path Control
- Chassis GND on board
- Filtered I/O
- Adequate Decoupling

Electrostatic Discharge

- LF Current Path Control
- Chassis GND on board
- Filtered I/O
- Adequate Decoupling

Bulk Current Injection

- 1 HF GND
- Chassis GND on board
- Filtered I/O
- Adequate Decoupling
- Balance Control

In 2011, CVEL began to guarantee that the automotive products they reviewed/designed would meet all automotive EMC requirements the first time they were tested.

What we are NOT doing

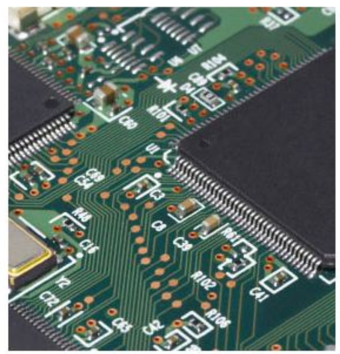
EMC Design Guideline Collection

Over the past 25 years, we've had opportunities to work with a wide variety of companies to solve circuit-board or system-level EMC problems. During this time, we've encountered all kinds of EMC design rules. Some of them are helpful, some not-so-helpful, and some practically guarantee that your product will have EMC problems.

Some people collect coins or stamps. We like to collect EMC design guidelines.

We've published our favorite EMC design rules (the good, the bad and the ugly) on this web site. Rules on this site were collected primarily from lists maintained by companies for internal use. Additional rules were gleaned from published books, technical papers and application notes. Please note that LearnEMC does not endorse any of the EMC design rules (we prefer to call them "guidelines") on this site. Like stamps or coins, our collection is being put on display for your information and entertainment. We hope you enjoy it!

- Why You Should Be Cautious About Using EMC Design Guidelines
- The Most Important EMC Design Guidelines
- Other Good EMC Design Guidelines
- Not-So-Good EMC Design Guidelines
- Some of the Worst EMC Design Guidelines
- Effective Application of EMC Design Guidelines
- Commercial EMC Rule Checkers



If you have a guideline that you'd be willing to share, please email it to info@LearnEMC.com. Be sure to indicate the source. We'd like to hear from you.

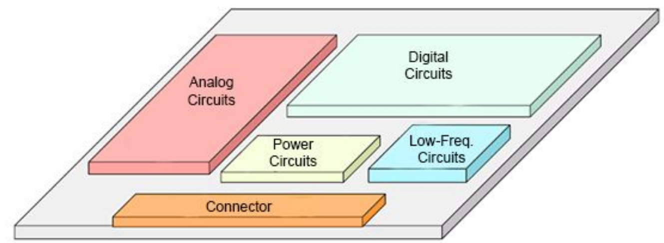
Updates or corrections to this web page should be emailed to webmaster@LearnEMC.com.
Return to LearnEMC Tutorials Page.

Some of the Worst EMC Design Guidelines

…cause more EMC problems than they prevent.

…board should be grouped by type with power circuits closest to the connector and …rthest from the connector.

…ariants …ngs) is …e crazy … other …line. It …ea that …ifferent … boards … signals … board … digital … the



…onsider …mponents when deciding where to place them. However, any general statements about placement relative to the connector are more likely to produce a bad design than a good one. Usually, but not always, it's a good idea to put the components that send or receive signals through the connector nearest the connector. Placement is important, but design guidelines that dictate placement without considering the function and signals …its are very dangerous.

…hould be gapped between analog and digital circuits.

Probably a close second in the competition for the worst EMC design guideline every conceived. There a some (very few) situations where gapping a ground plane between analog and digital circuits is a good idea. These situations are …

NOT Relying on EMC Design Guidelines

What we are NOT doing

Numerical EM modeling codes give precise answers to precisely defined problems. EMC geometries are not well-defined.

We don't want to know how much a given configuration will radiate. The answer to that question depends on a lot of factors that we have no control over.

We want to know if our product will meet its requirements.

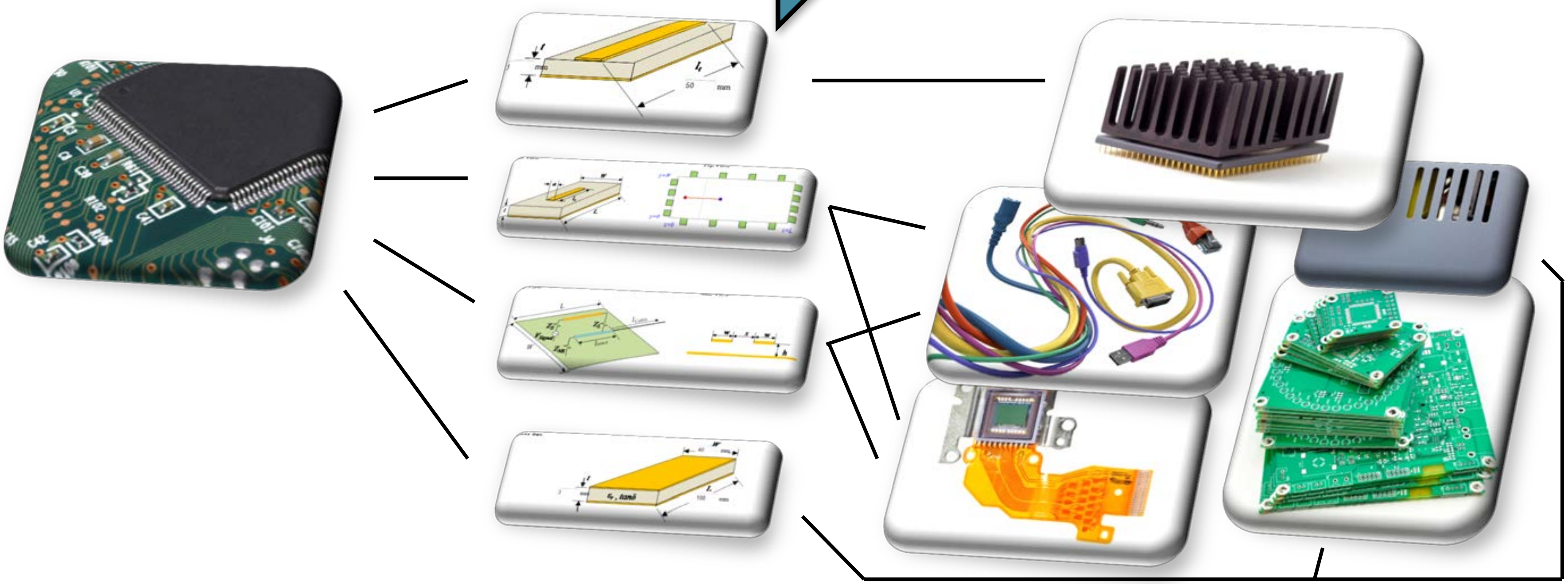
NOT Modeling Products with Numerical EM Modeling Codes

What we ARE doing

SOURCE

COUPLING MECHANISM

ANTENNA



Identifying all possible sources, victims and coupling paths

History

1989

Begin development of numerical modeling software for EMC analysis at UMR

1995

Formation of EMC Expert System Consortium

Investigation of fundamental EMI source mechanisms driving common-mode radiation from printed circuit boards with attached cables, IEEE Trans. on EMC, Nov. 1996.

~40 publications relating to ability of various PCB structures to radiate

Development of algorithms for calculating radiated emissions and EM coupling for various PCB structures

2006

First Maximum Radiated Emission Calculator (MREMC)

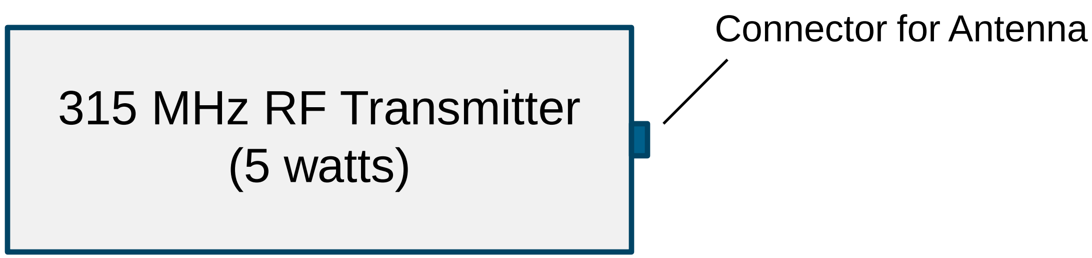
Estimating maximum radiated emissions from printed circuit boards with an attached cable, IEEE Trans. on EMC, Feb. 2008.

Calculating radiated emissions due to I/O line coupling on printed circuit boards using the imbalance difference method," IEEE Trans. on EMC, Feb. 2012.

2013

Development of Performance-Based Design for EMC Process

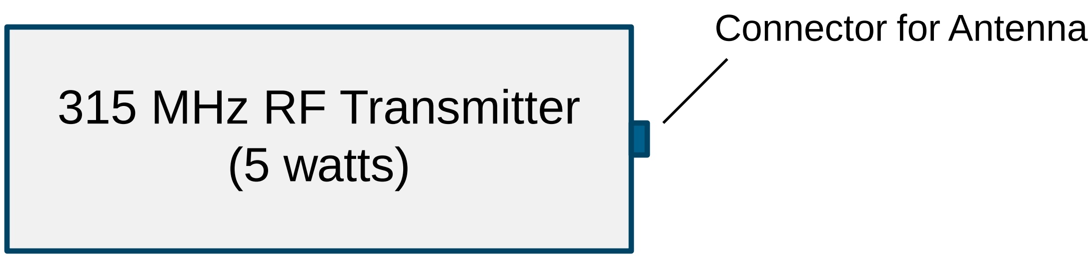
Maximum Radiated Emissions Concept



What is the maximum 3-meter radiated field strength at 315 MHz?

a. impossible to predict without knowing what antenna is connected
b. impossible to predict even if the antenna is known
c. 15 V/m
d. none of the above

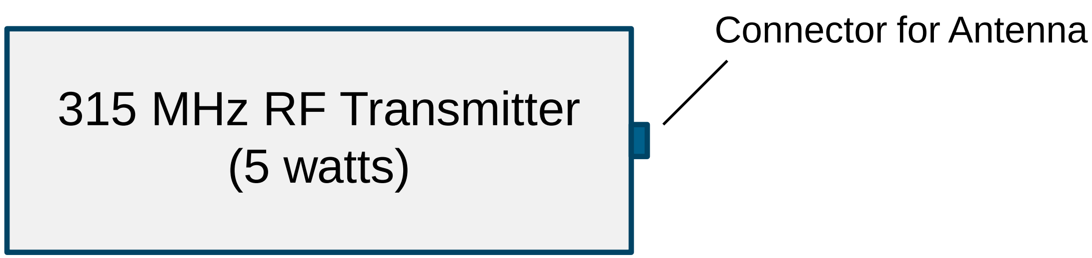
Maximum Radiated Emissions Concept



What is the maximum 3-meter radiated field strength at 315 MHz?

$$P_{rec} = \frac{P_{rad}}{4\pi r^2} D_0 = \frac{1}{2} \frac{|E|^2}{\eta} \qquad |E_{\max}| = \sqrt{\frac{\eta P_{rad}}{2\pi r^2} D_0}$$

Maximum Radiated Emissions Concept



What is the maximum 3-meter radiated field strength at 315 MHz?

$$\left|E_{\max}\right| = \sqrt{\frac{\eta P_{rad}}{2\pi r^2} D_0} = \sqrt{\frac{(377\Omega)(5\,\text{W})}{2\pi(3\,\text{m})^2}(6.4)} = 14.6\,\text{V/m}$$

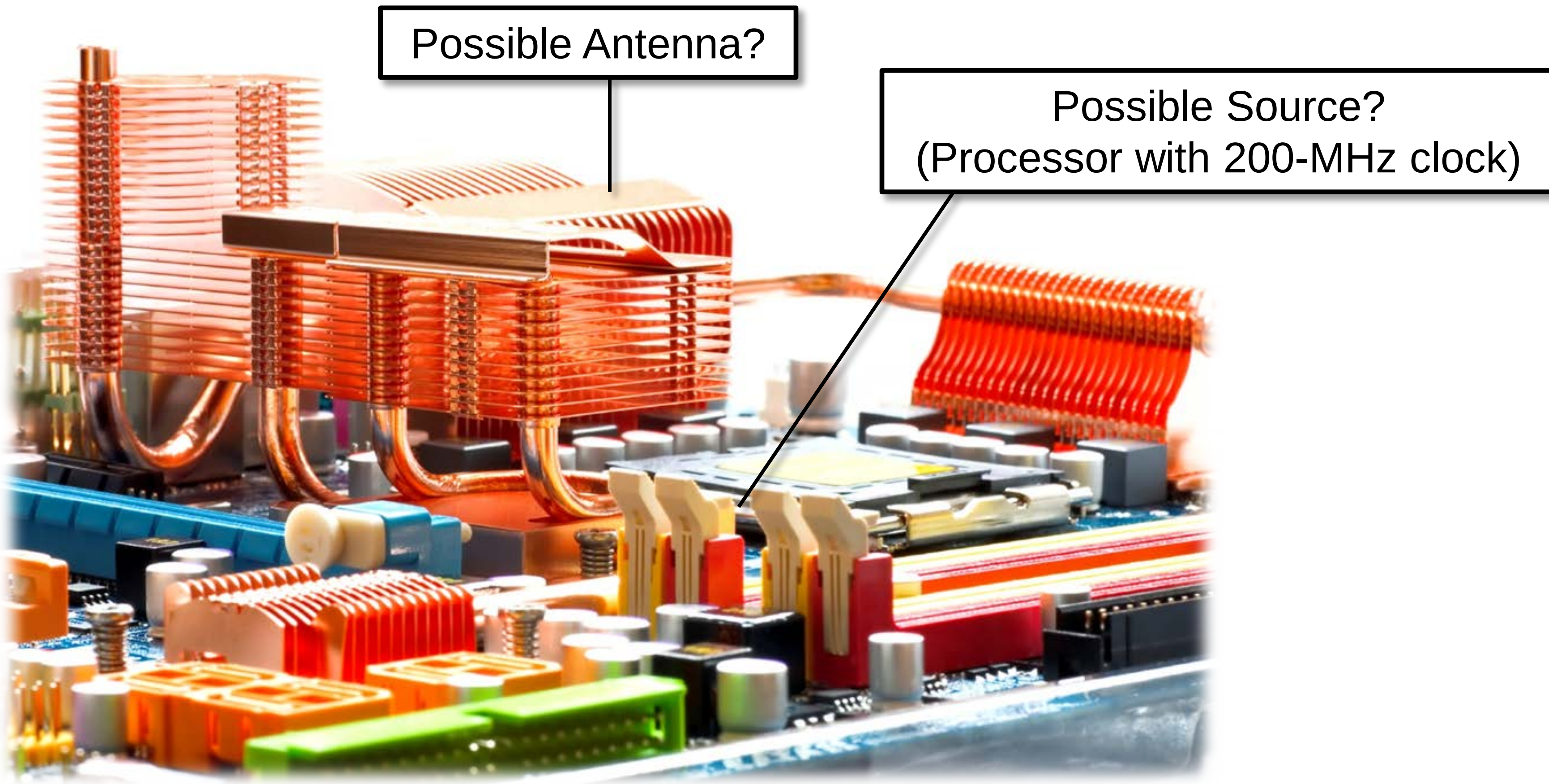
Maximum Radiated Emissions Concept

What is the maximum 3-meter radiated field strength at 200 MHz?

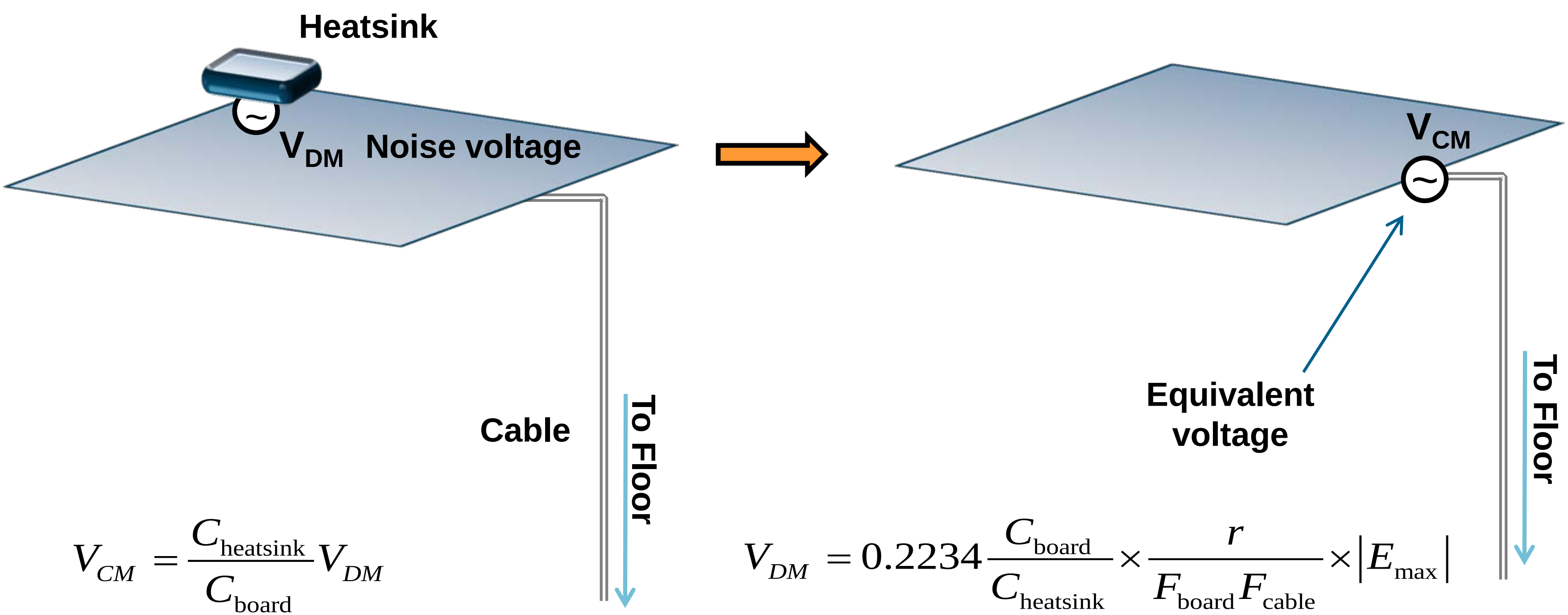
We can put an upper bound on the radiated emissions at any given frequency!

The more we know about the product design, the lower this upper bound becomes.

Maximum Radiated Emissions Concept



Maximum Radiated Emissions Calculation



$$V_{CM} = \frac{C_{\text{heatsink}}}{C_{\text{board}}} V_{DM}$$

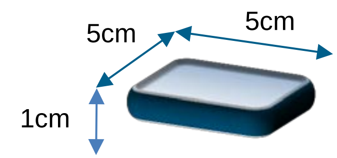
$$V_{DM} = 0.2234 \frac{C_{\text{board}}}{C_{\text{heatsink}}} \times \frac{r}{F_{\text{board}} F_{\text{cable}}} \times |E_{\max}|$$

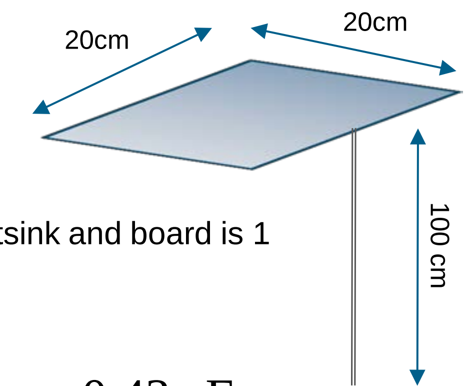
References

[1] H. Shim and T. Hubing, "Model for Estimating Radiated Emissions from a Printed Circuit Board with Attached Cables Driven by Voltage-Driven Sources," IEEE Transactions on Electromagnetic Compatibility, vol. 47, no. 4, Nov. 2005, pp. 899-907.

[2] Shaowei Deng, Todd Hubing, and Daryl Beetner, "Estimating Maximum Radiated Emissions From Printed Circuit Boards With an Attached Cable," IEEE Trans. on Electromagnetic Compatibility, vol. 50, no. 1, Feb. 2008, pp. 215-218.

Maximum Radiated Emissions Calculation

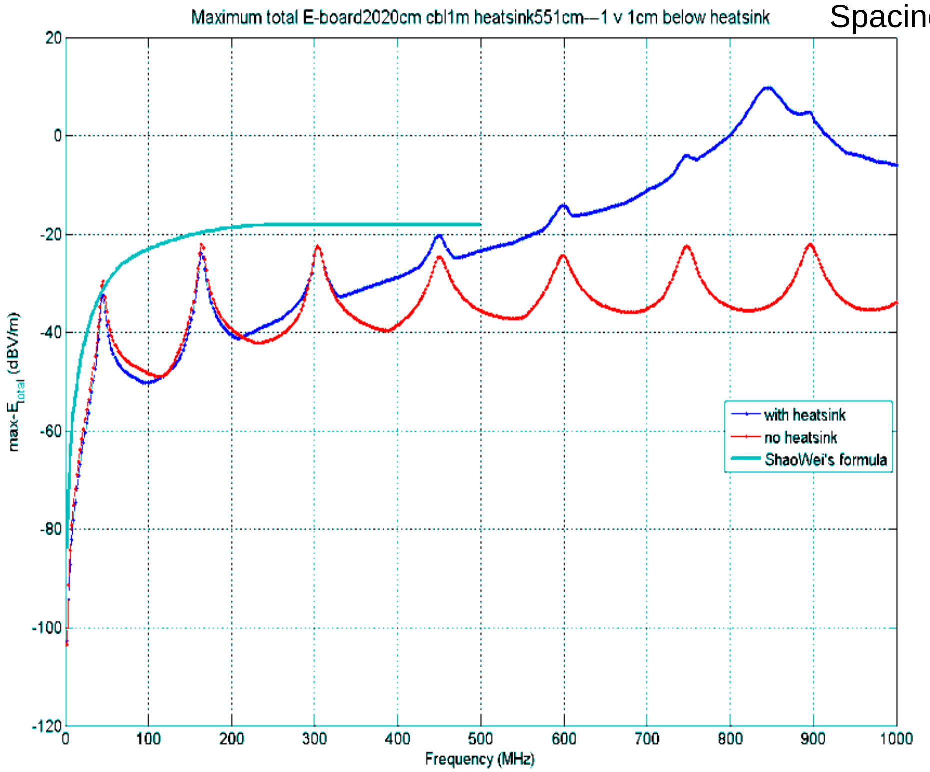




Spacing between heatsink and board is 1 cm

$$C_{\text{heatsink}} = 0.43\ \text{pF}$$

$$C_{\text{board}} = 5.14\ \text{pF}$$



Maximum Radiated Emissions Calculator

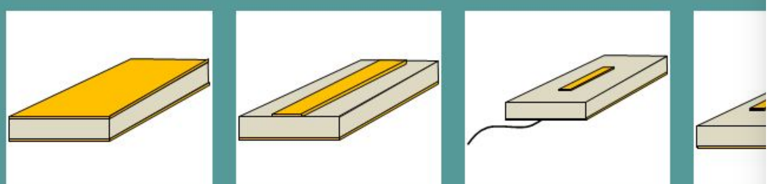
CVEL
ELECTROMAGNETIC MODELING
THE CLEMSON UNIVERSITY VEHICULAR ELEC

Maximum Radiated Emissions Calculator (MR EMC)

Welcome to the beta test site for the Maximum Radiated Emissions Calculator. This calculator determines the maxim emissions from various printed circuit board structures. In addition to calculating the radiated emissions directly from calculate the maximum possible radiated emissions from cables and structures connected to the board **even when t those structures has not been specified**.

The calculator works based on the assumption that everything that is unknown is worst case. For example if you kno attached to your board, but you don't specify their size or geometry, the calculator assumes that they are resonant at

Currently, the calculator evaluates different types of radiation using separate algorithms. Therefore, if you want to kn radiated emissions due to noise on a microstrip trace being radiated directly from the circuit board, you would choose calculator. If you want to know the maximum amount of radiated emissions due to noise on a microstrip trace being r attached to the circuit board, you would choose the common-mode EMI calculator. Eventually, these algorithms will a the same input file making it unnecessary to select a particular radiation mechanism before you start.



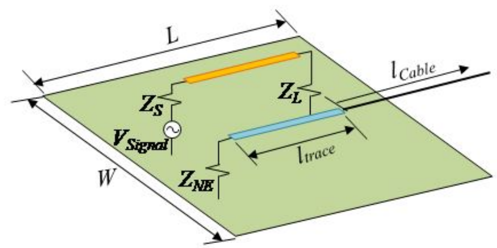
Power-bus EMI Calculator | Differential-mode EMI Calculator | Common-mode EMI Calculator | I/O C

This material is based upon work supported by the National Science Foundation I/UCRC for Electromagnetic Compatibility. Any opinions, findings and conc expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation (NSF)

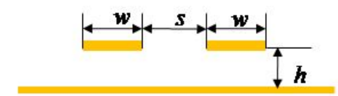
I/O Coupling EMI Calculator

High frequency signals can couple to I/O nets that carry the coupled energy away from the board. The common-mode currents induced on cables attached to I/O nets can result in significant radiated emissions. A closed-form expression is developed to estimate the maximum radiated emission [1].

Top View



Side View



Board

Length (L) = 100 mm Width (W) = 100 mm
Dielectric constant (ε_r) = 1

Circuit Terminations

Z_S= 50 Ohm Z_L= 50 Ohm Z_{NE}= 50 Ohm

Traces

Width (a) = 0.5 mm Distance (s) = 0.5 mm
Height (t) = 1 mm
Coupling length ($l_{coupling}$) = 20 mm
I/O line length (l_{trace}) = 100 mm

Voltage Source

Swept Frequency - Constant Voltage

Amplitude A): 1 V
Lower frequency (f_0): 10 MHz
Upper frequency (f_1): 1000 MHz

Calculate Emission

[1] C. Su, and T. Hubing, Estimating Maximum Radiated Emissions from a Printed Circuit Board due to Coupling between High-speed and I/O Traces, 2010.

← Return to MR EMC

Performance-Based EMC Design Procedure

Step I: For each net on each board:

1. Determine worst-case signal characteristics
2. Calculate maximum possible emissions from signal driving matched antenna
3. If > limit at any frequency, control risetime with series resistor
4. Recalculate maximum possible emissions from signal driving matched antenna
5. Proceed to Step II.

MS Excel Spreadsheet Calculation

Microcontroller Output Specification

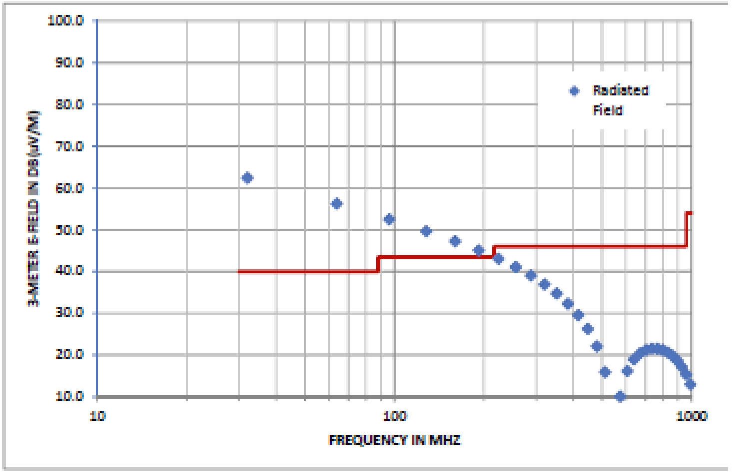
VOH = 3.3 | IMAX = 2.00E-02 | Cin = 5.00E-12 | Rsource = 165

Clock Period = 1.00E-05

Clock Frequency = 1.00E+05 | Rseries = 0 | Risetime = 1.82E-09

32

	Frequency in MHz	harmonic	Source Amplitude	Max. Power	E-Field	in dB(uV/m)	FCC Limit
1	32	320	6.56E-03	1.30542E-07	0.001319	62.4	40.0
2	64	640	3.23E-03	3.15609E-08	0.000648	56.2	40.0
3	96	960	2.09E-03	1.32591E-08	0.00042	52.5	43.5
4	128	1280	1.51E-03	6.88529E-09	0.000303	49.6	43.5
5	160	1600	1.14E-03	3.96836E-09	0.00023	47.2	43.5
6	192	1920	8.93E-04	2.41686E-09	0.000179	45.1	43.5
7	224	2240	7.07E-04	1.51306E-09	0.000142	43.0	46.0
8	256	2560	5.62E-04	9.56073E-10	0.000113	41.1	46.0
9	288	2880	4.45E-04	6.01225E-10	8.95E-05	39.0	46.0
10	320	3200	3.50E-04	3.71477E-10	7.03E-05	36.9	46.0
11	352	3520	2.71E-04	2.22441E-10	5.44E-05	34.7	46.0
12	384	3840	2.05E-04	1.26876E-10	4.11E-05	32.3	46.0
13	416	4160	1.49E-04	6.7212E-11	2.99E-05	29.5	46.0
14	448	4480	1.02E-04	3.16704E-11	2.05E-05	26.3	46.0
15	480	4800	6.33E-05	1.21383E-11	1.27E-05	22.1	46.0
16	512	5120	3.11E-05	2.9375E-12	6.26E-06	15.9	46.0
17	544	5440	4.97E-06	7.48254E-14	9.98E-07	0.0	46.0
18	576	5760	1.59E-05	7.64433E-13	3.19E-06	10.1	46.0
19	608	6080	3.20E-05	3.10586E-12	6.43E-06	16.2	46.0
20	640	6400	4.40E-05	5.85655E-12	8.83E-06	18.9	46.0
21	672	6720	5.22E-05	8.26307E-12	1.05E-05	20.4	46.0
22	704	7040	5.72E-05	9.93106E-12	1.15E-05	21.2	46.0
23	736	7360	5.95E-05	1.07222E-11	1.2E-05	21.5	46.0
24	768	7680	5.93E-05	1.06714E-11	1.19E-05	21.5	46.0
25	800	8000	5.72E-05	9.92083E-12	1.15E-05	21.2	46.0
26	832	8320	5.35E-05	8.66748E-12	1.07E-05	20.6	46.0
27	864	8640	4.85E-05	7.12361E-12	9.74E-06	19.8	46.0
28	896	8960	4.26E-05	5.48798E-12	8.55E-06	18.6	46.0
29	928	9280	3.60E-05	3.927E-12	7.23E-06	17.2	46.0
30	960	9600	2.91E-05	2.56426E-12	5.84E-06	15.3	54.0
31	992	9920	2.21E-05	1.47711E-12	4.44E-06	12.9	54.0

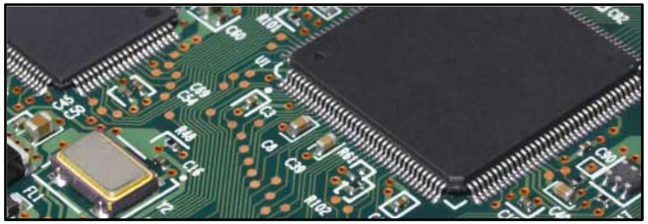


Design Review Procedure

Step II: For each net at each frequency over the limit:

1. Determine worst-case emissions due to each of the 5 MREMC algorithms that apply to your design
2. For any net that does not meet the specification at every frequency as determined by a given algorithm, adjust the design until the net is compliant.

Example 1: Microcontroller Output Driver



Automotive microcontroller in typical application:

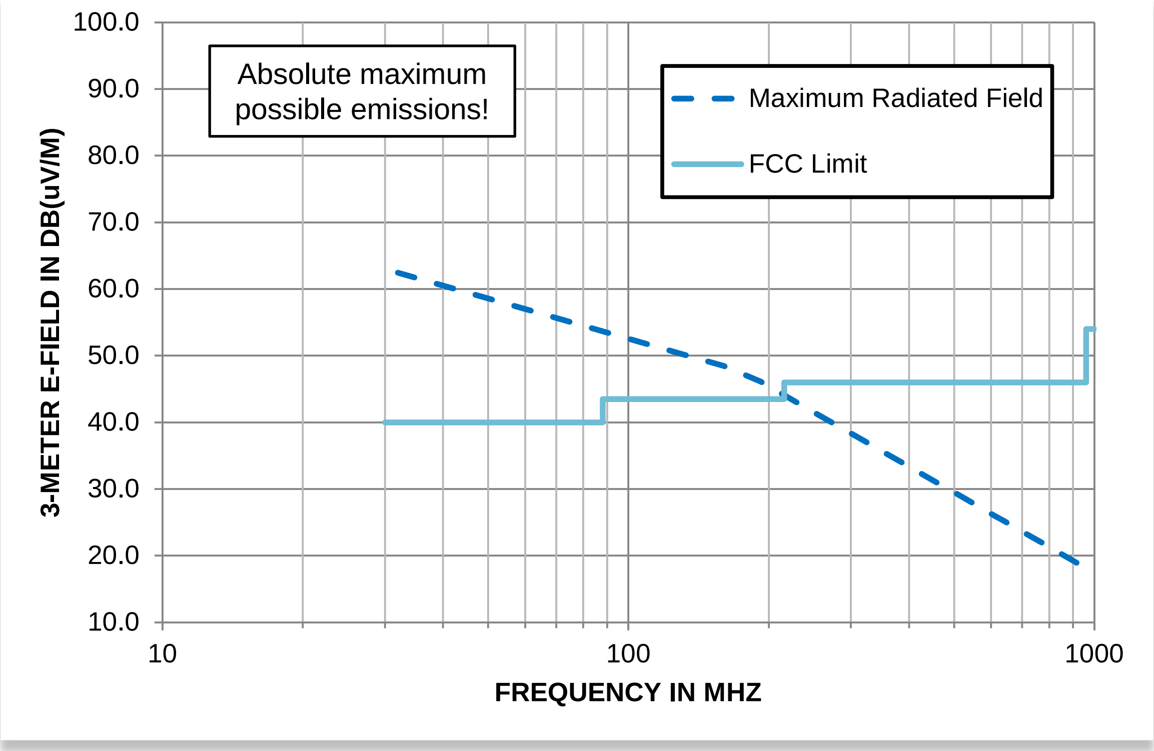
Suppose we connected an output of this microcontroller directly up to an impedance-matched antenna…

Available Information

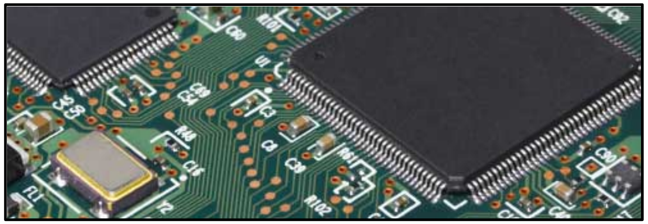
- V_{source} = 3.3 V
- I_{max} = 20 mA
- C_{in} = 5 pF
- R_{series} = 0 Ω
- CLK Freq = 100 kHz

Calculated Parameters

- R_{source} = 165 Ω
- T = 10 μs
- t_r = 1.82 ns



Example 1: Microcontroller Output Driver



Same output with 20-kΩ series resistor:

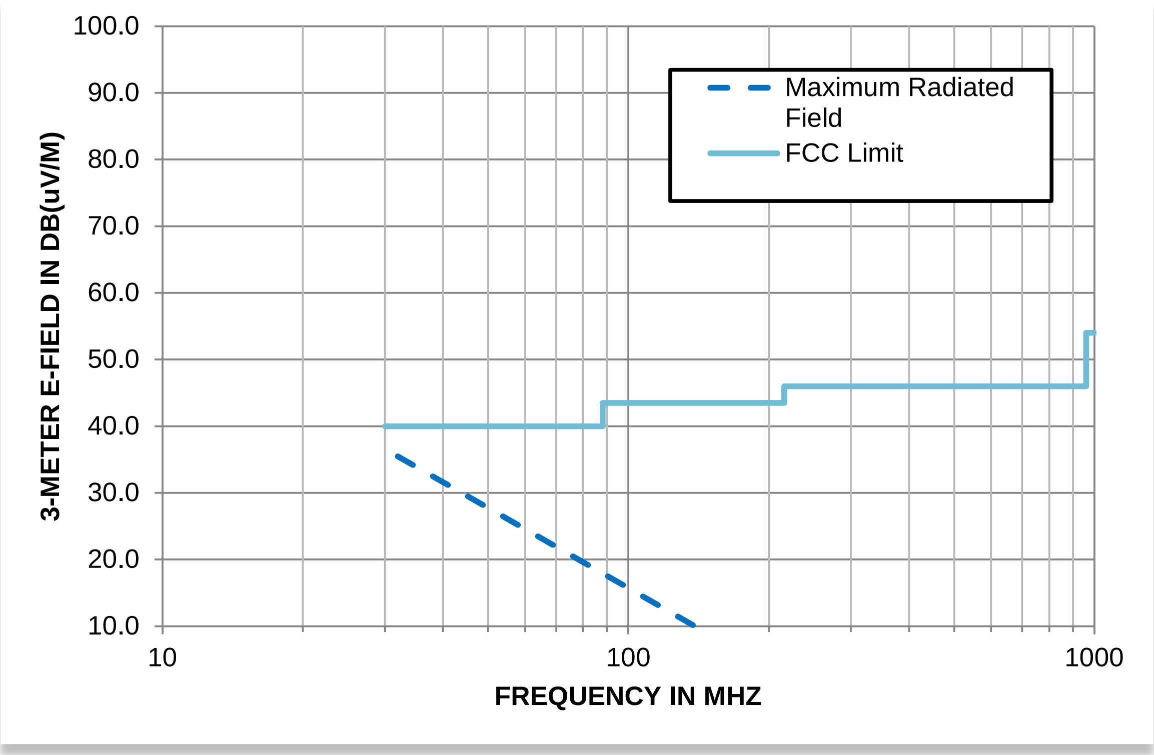
Suppose we connected an output of this microcontroller directly up to an impedance-matched antenna…

Available Information

- V_{source} = 3.3 V
- I_{max} = 20 mA
- C_{in} = 5 pF
- **R_{series} = 20 kΩ**
- CLK Freq = 100 kHz

Calculated Parameters

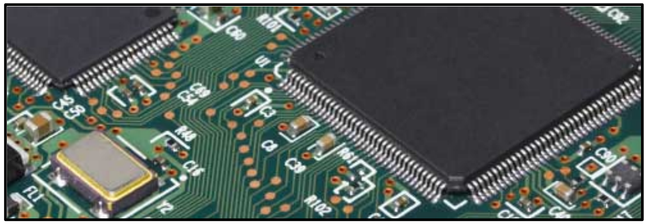
- R_{source} = 8165 Ω
- T = 10 μs
- t_r = 220.0 ns



Why use series resistors to control transition times?

- Optimal control
- Minimal cost / Minimal footprint
- Predictable behavior
- Easy to adjust without affecting layout
- Reduces power bus noise

Example 2: Microcontroller Output Driver



Same output with 1 MHz output:

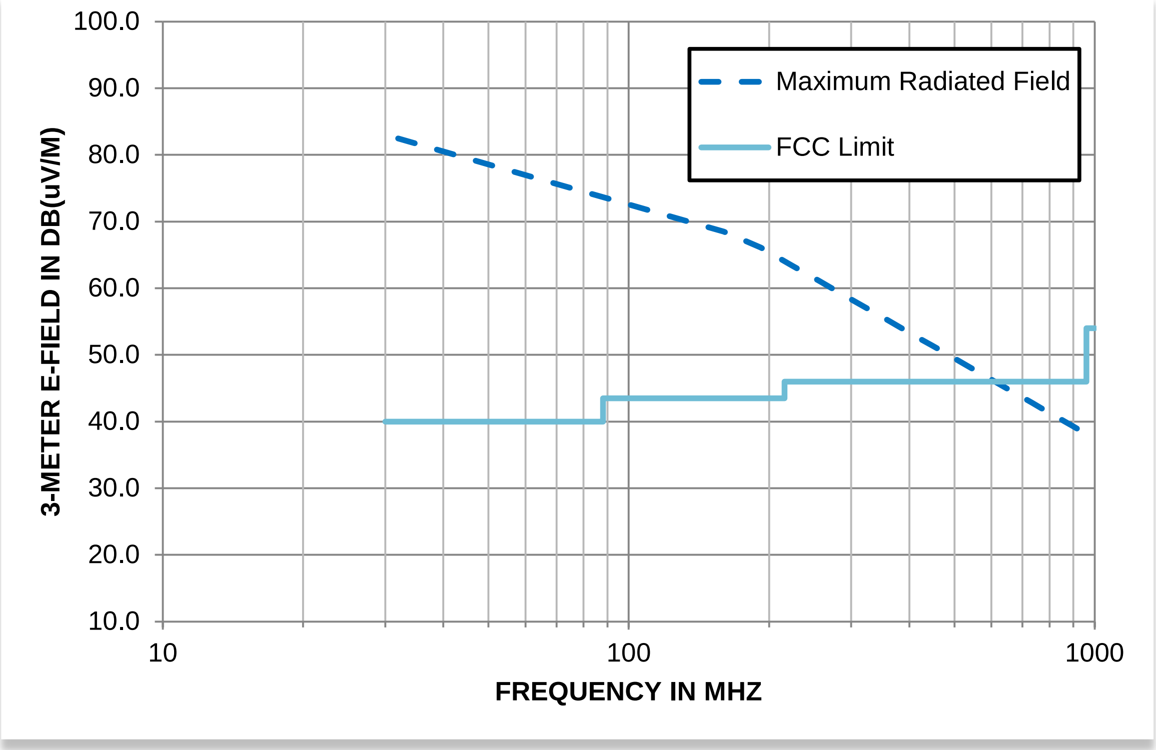
Suppose we connected an output of this microcontroller directly up to an impedance-matched antenna…

Available Information

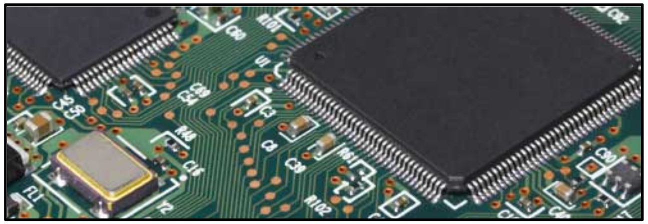
- V_{source} = 3.3 V
- I_{max} = 20 mA
- C_{in} = 5 pF
- R_{series} = 0 kΩ
- CLK Freq = 1 MHz

Calculated Parameters

- R_{source} = 165 Ω
- T = 1 μs
- t_r = 1.82 ns



Example 2: Microcontroller Output Driver



Same output with 1 MHz output and 8-kΩ series resistor:

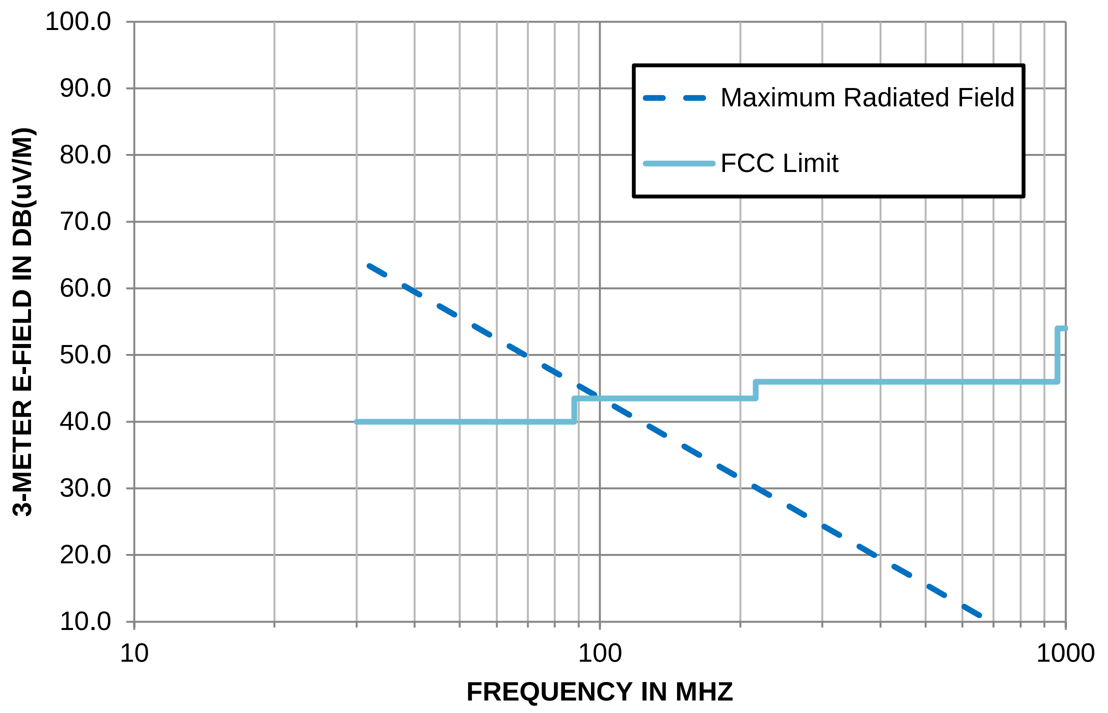
Suppose we connected an output of this microcontroller directly up to an impedance-matched antenna…

Available Information

- V_{source} = 3.3 V
- I_{max} = 20 mA
- C_{in} = 5 pF
- **R_{series} = 8 kΩ**
- CLK Freq = 1 MHz

Calculated Parameters

- R_{source} = 8165 Ω
- T = 1 μs
- t_r = 90 ns



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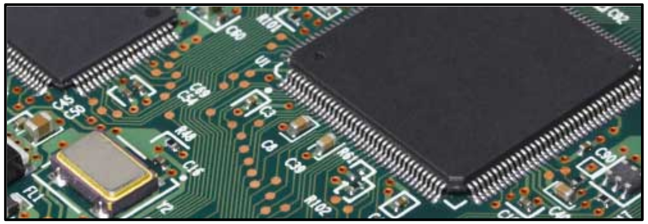
Example 3: Xilinx Vertex-6 FPGA SelectIO™



With 1 MHz output :

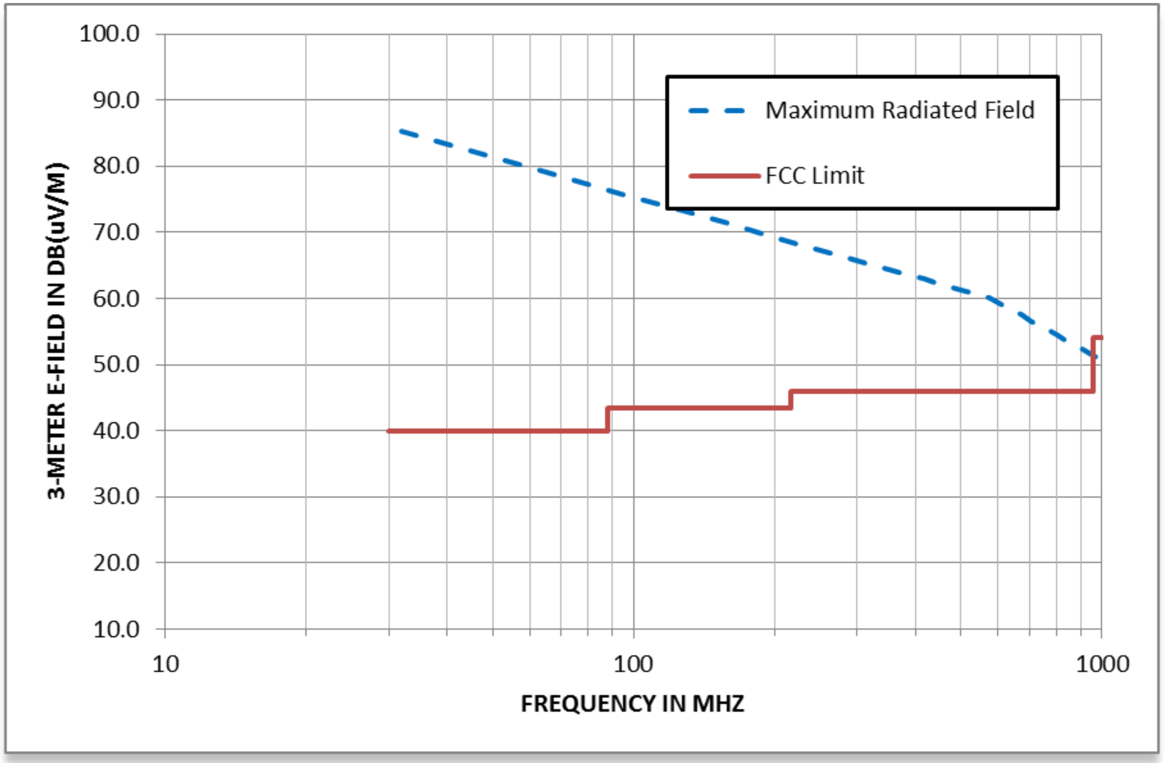
Suppose we connected an output of this FPGA directly up to an impedance-matched antenna…

Available Information

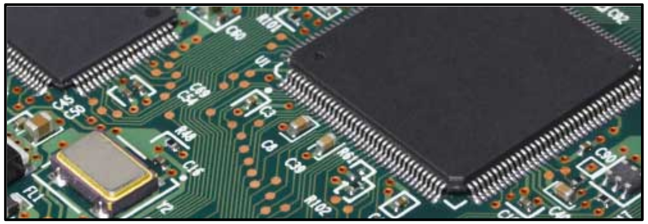
- V_{source} = 2.5 V
- I_{max} = 240 mA*
- C_{in} = 5 pF
- R_{series} = 0 kΩ
- CLK Freq = 1 MHz

Calculated Parameters

- R_{source} = 50 Ω
- T = 1 μs
- t_r = 0.55 ns



Example 3: Xilinx Vertex-6 FPGA SelectIO™



With 1 MHz output and 20-kΩ series resistor:

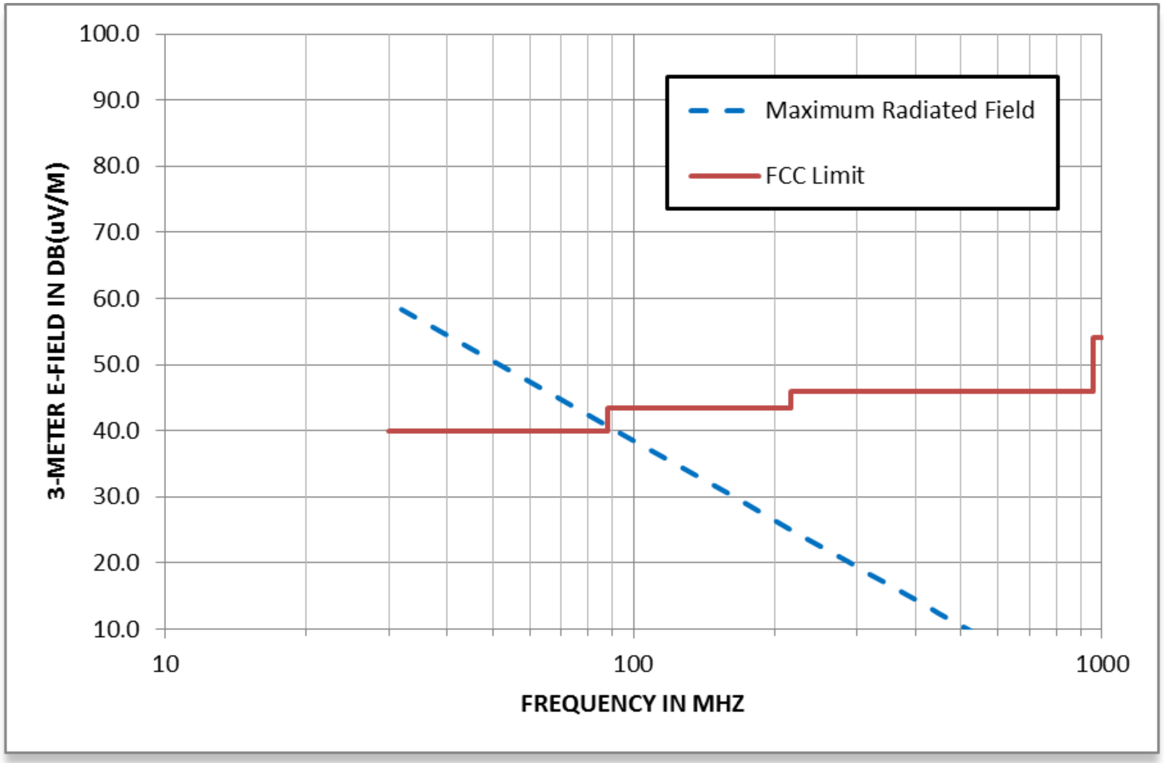
Suppose we connected an output of this FPGA directly up to an impedance-matched antenna…

Available Information

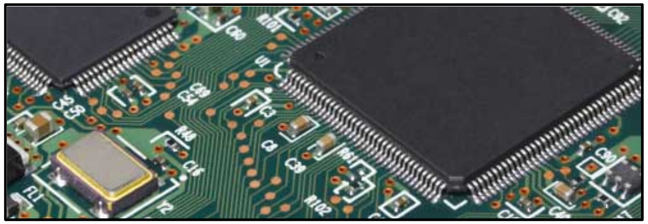
- V_{source} = 2.5 V
- I_{max} = 240 mA*
- C_{in} = 5 pF
- **R_{series} = 20 kΩ**
- CLK Freq = 1 MHz

Calculated Parameters

- R_{source} = 50 Ω
- T = 1 μs
- t_r = 221 ns



Example 4: Xilinx Vertex-6 FPGA SelectIO™



With 32 MHz output and 0-Ω series resistor:

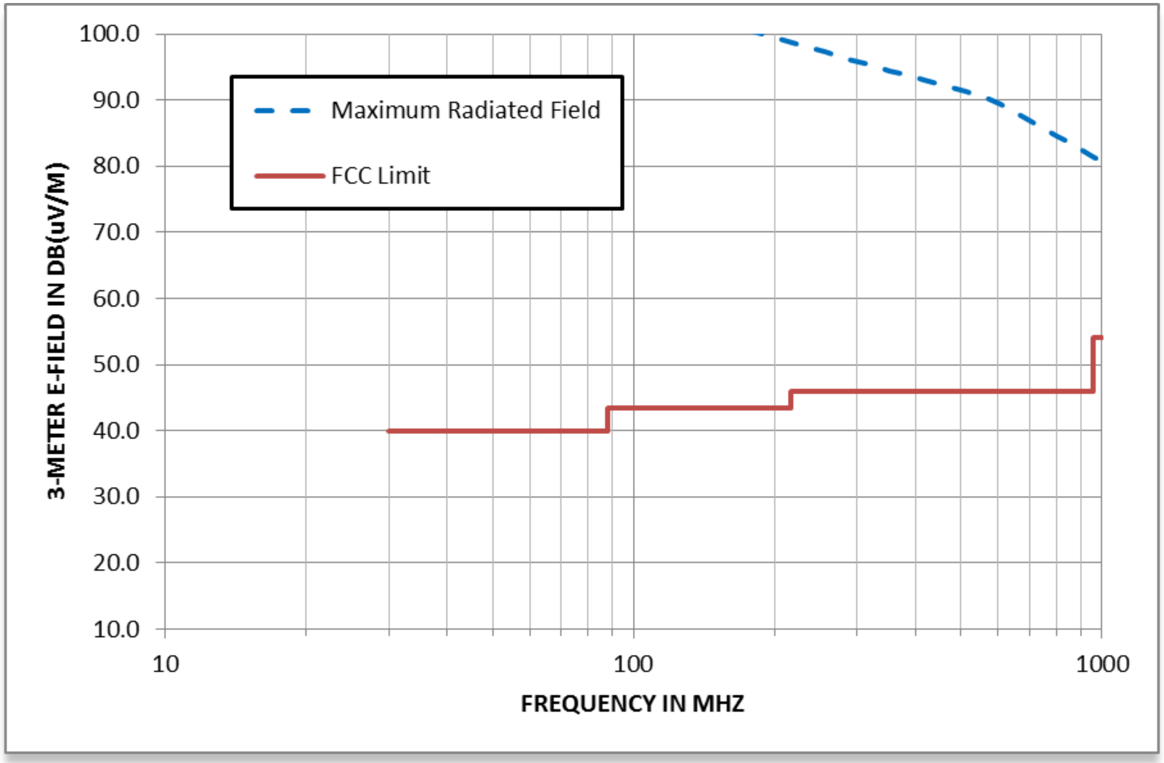
Suppose we connected an output of this FPGA directly up to an impedance-matched antenna…

Available Information

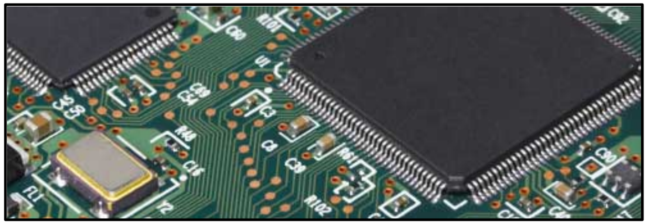
- V_{source} = 2.5 V
- I_{max} = 240 mA*
- C_{in} = 5 pF
- R_{series} = 0 kΩ
- CLK Freq = 32 MHz

Calculated Parameters

- R_{source} = 50 Ω
- T = 31 ns
- t_r = 0.55 ns



Example 4: Xilinx Vertex-6 FPGA SelectIO™



With 32 MHz output and 500-Ω series resistor :

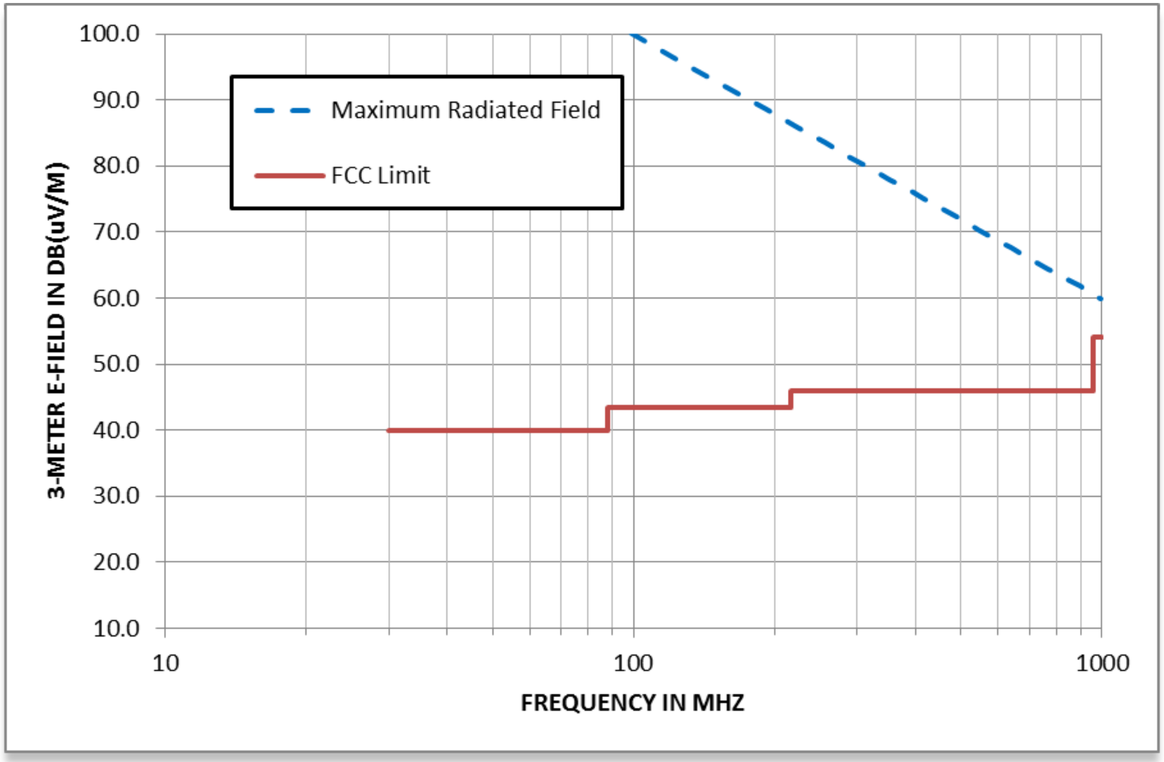
Suppose we connected an output of this FPGA directly up to an impedance-matched antenna…

Available Information

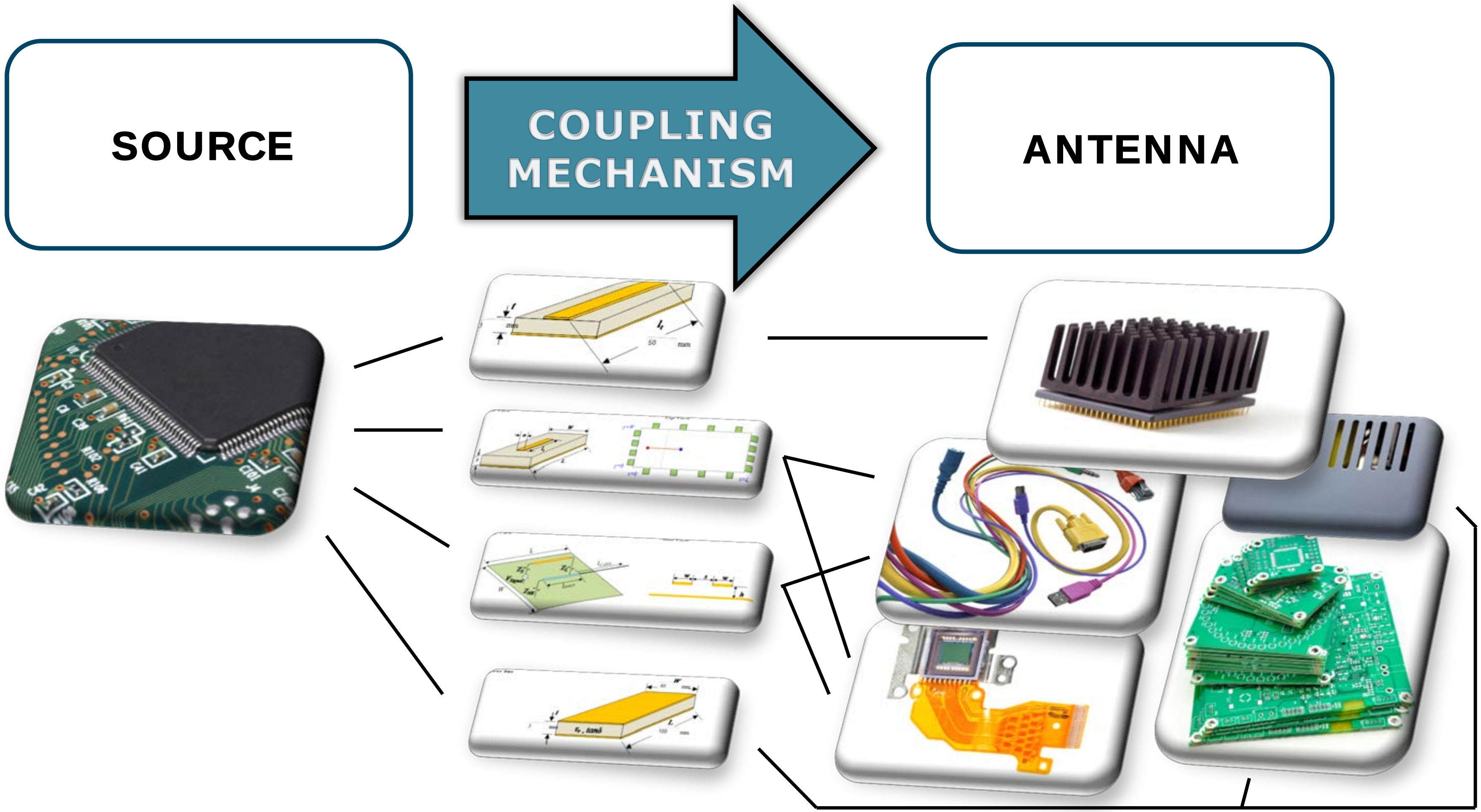
- V_{source} = 2.5 V
- I_{max} = 240 mA*
- C_{in} = 5 pF
- R_{series} = 500 Ω
- CLK Freq = 32 MHz

Calculated Parameters

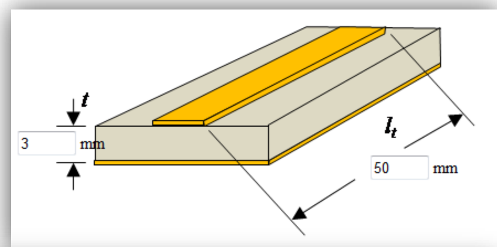
- R_{source} = 50 Ω
- T = 31 ns
- t_r = 6.0 ns

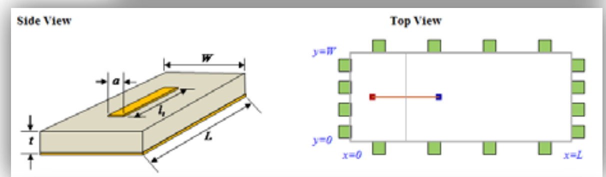


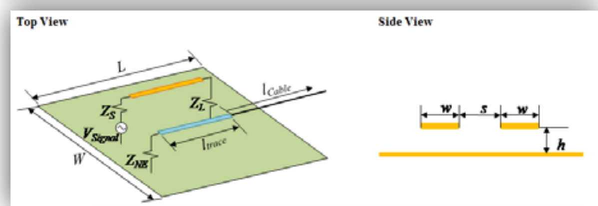
3 Elements of a Radiated Emissions Problem

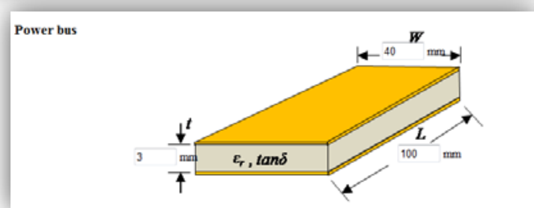


MREMC Algorithms (Nets)









Direct Radiation from Trace

Need to know: net dimensions

Trace Drives an Attached Cable and/or Heatsink

Need to know: net dimensions, net placement, connector placement, and board dimensions

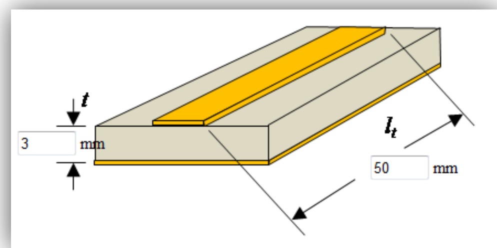
Trace Couples to another Trace that Drives an Attached Cable

Need to know: net dimensions, net placement, connector placement, and board dimensions

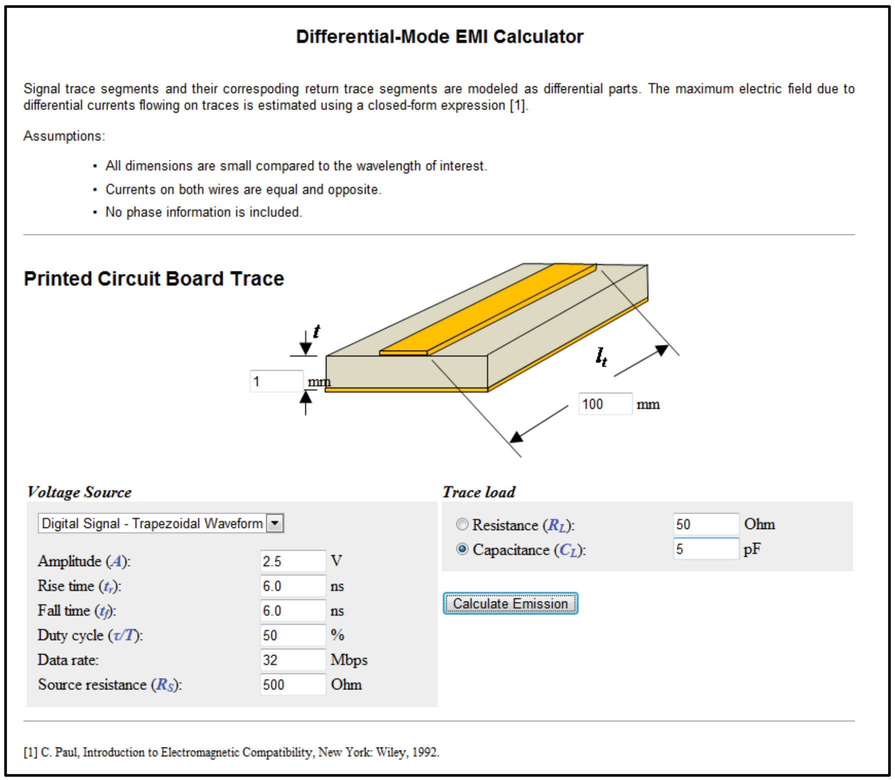
Trace Drives the Power Bus

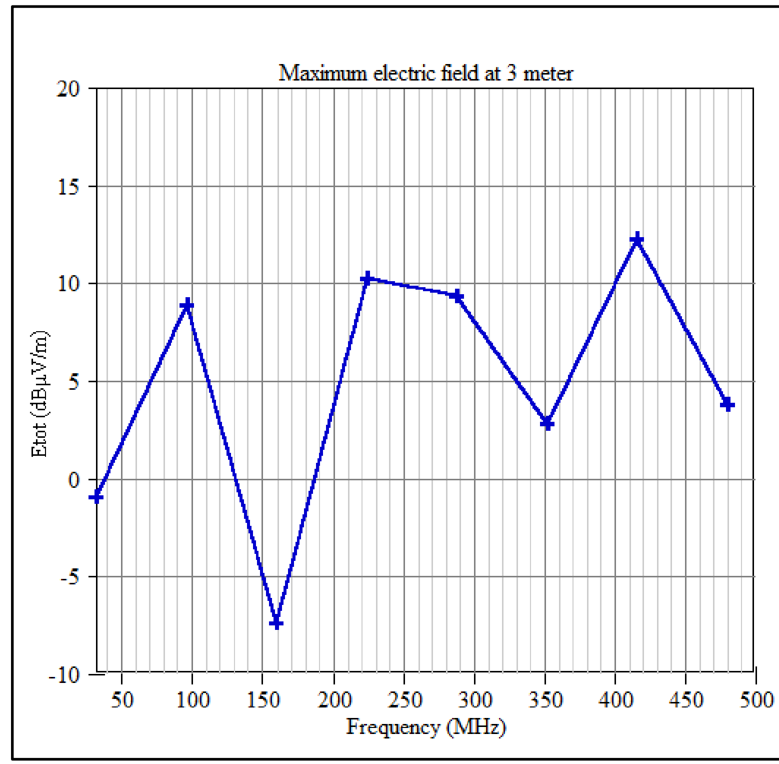
Need to know: board dimensions

MREMC Algorithms (Nets)

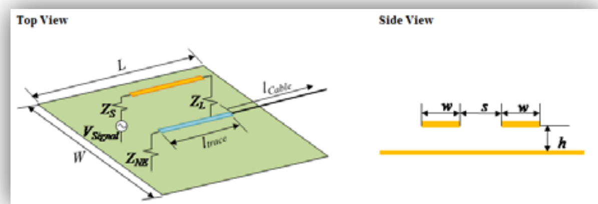


Direct Radiation from 10-cm trace, 1-mm above plane

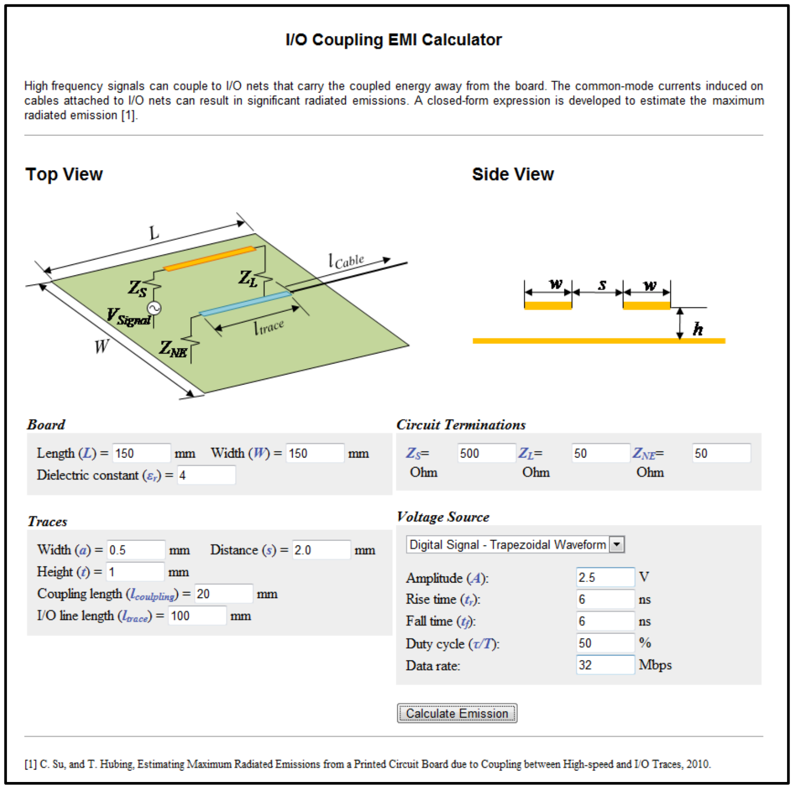




MREMC Algorithms (Nets)



Trace Couples to another Trace that Drives an Attached Cable



I/O Coupling EMI Calculator

High frequency signals can couple to I/O nets that carry the coupled energy away from the board. The common-mode currents induced on cables attached to I/O nets can result in significant radiated emissions. A closed-form expression is developed to estimate the maximum radiated emission [1].

Top View **Side View**

Board

Length (L) = 150 mm Width (W) = 150 mm
Dielectric constant (ε_r) = 4

Circuit Terminations

Z_S= 500 Ohm Z_L= 50 Ohm Z_{NE}= 50 Ohm

Traces

Width (a) = 0.5 mm Distance (s) = 2.0 mm
Height (t) = 1 mm
Coupling length ($l_{coupling}$) = 20 mm
I/O line length (l_{trace}) = 100 mm

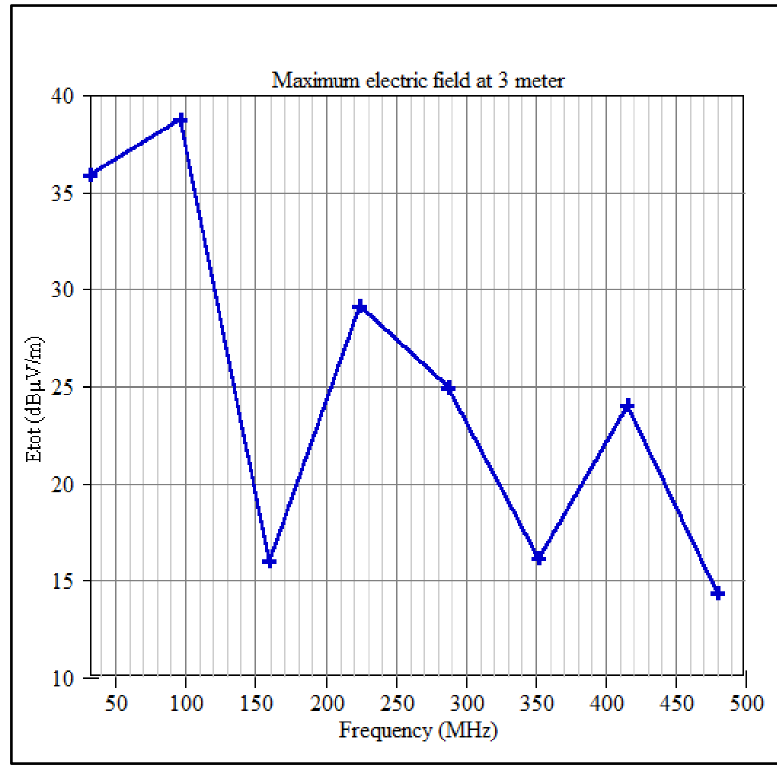
Voltage Source

Digital Signal - Trapezoidal Waveform

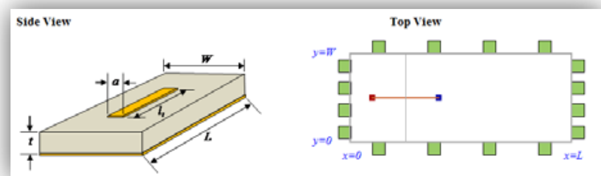
Amplitude (A): 2.5 V
Rise time (t_r): 6 ns
Fall time (t_f): 6 ns
Duty cycle (τ/T): 50 %
Data rate: 32 Mbps

Calculate Emission

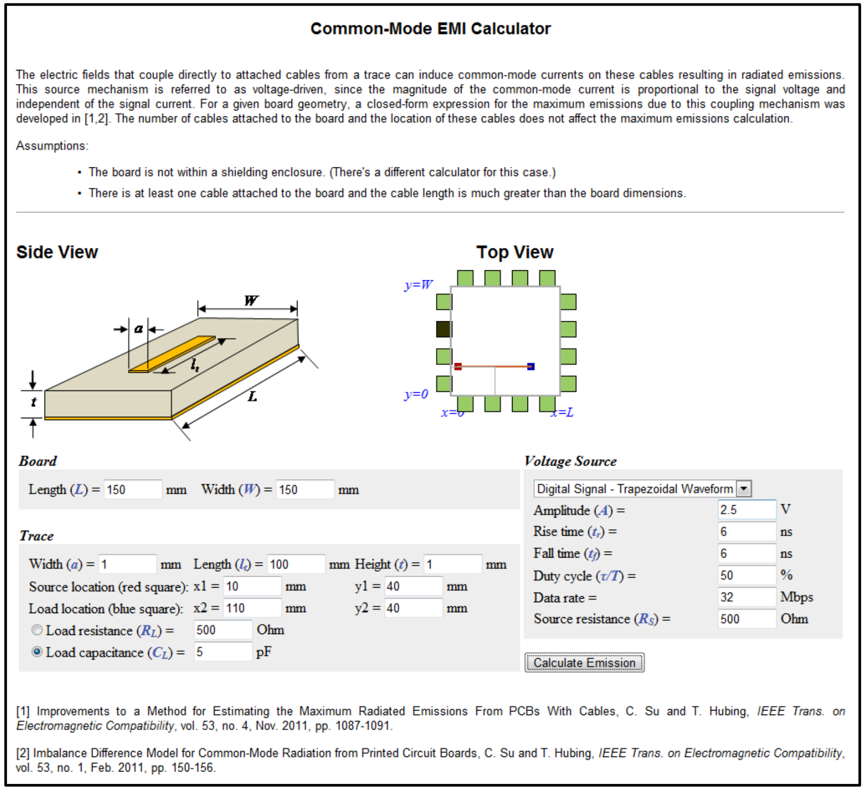
[1] C. Su, and T. Hubing, Estimating Maximum Radiated Emissions from a Printed Circuit Board due to Coupling between High-speed and I/O Traces, 2010.



MREMC Algorithms (Nets)



Trace Drives an Attached Cable and/or Heatsink



Common-Mode EMI Calculator

The electric fields that couple directly to attached cables from a trace can induce common-mode currents on these cables resulting in radiated emissions. This source mechanism is referred to as voltage-driven, since the magnitude of the common-mode current is proportional to the signal voltage and independent of the signal current. For a given board geometry, a closed-form expression for the maximum emissions due to this coupling mechanism was developed in [1,2]. The number of cables attached to the board and the location of these cables does not affect the maximum emissions calculation.

Assumptions:

- The board is not within a shielding enclosure. (There's a different calculator for this case.)
- There is at least one cable attached to the board and the cable length is much greater than the board dimensions.

Side View **Top View**

Board

Length (L) = 150 mm Width (W) = 150 mm

Trace

Width (a) = 1 mm Length (l_t) = 100 mm Height (t) = 1 mm

Source location (red square): x1 = 10 mm y1 = 40 mm

Load location (blue square): x2 = 110 mm y2 = 40 mm

Load resistance (R_L) = 500 Ohm

Load capacitance (C_L) = 5 pF

Voltage Source

Digital Signal - Trapezoidal Waveform

Amplitude (A) = 2.5 V

Rise time (t_r) = 6 ns

Fall time (t_f) = 6 ns

Duty cycle (τ/T) = 50 %

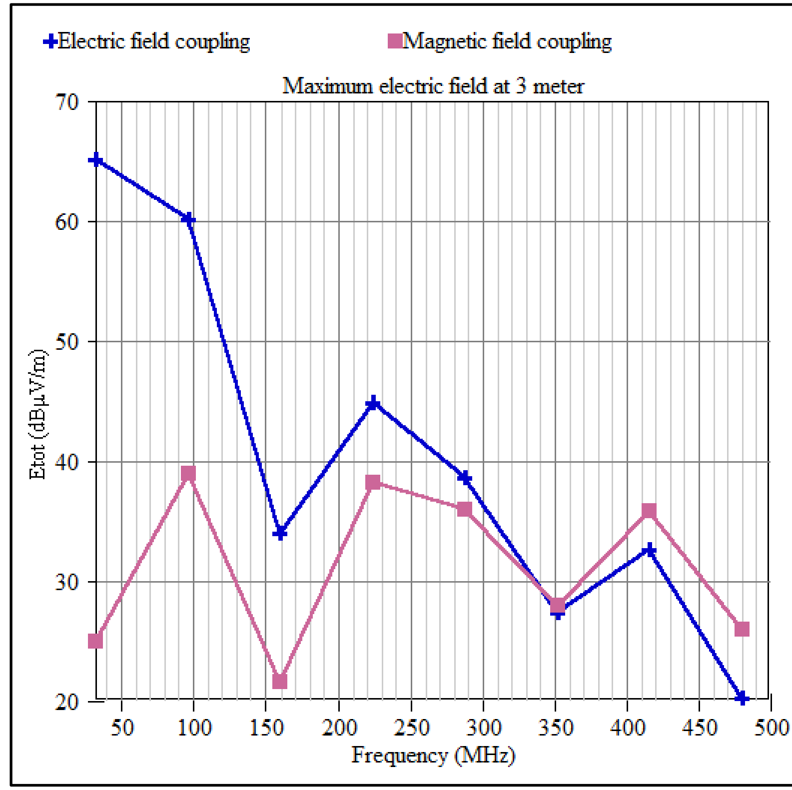
Data rate = 32 Mbps

Source resistance (R_S) = 500 Ohm

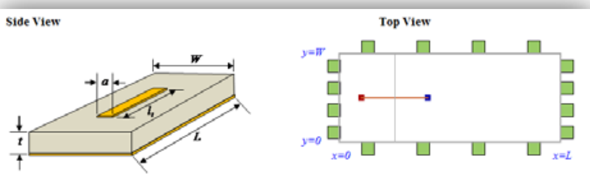
Calculate Emission

[1] Improvements to a Method for Estimating the Maximum Radiated Emissions From PCBs With Cables, C. Su and T. Hubing, *IEEE Trans. on Electromagnetic Compatibility*, vol. 53, no. 4, Nov. 2011, pp. 1087-1091.

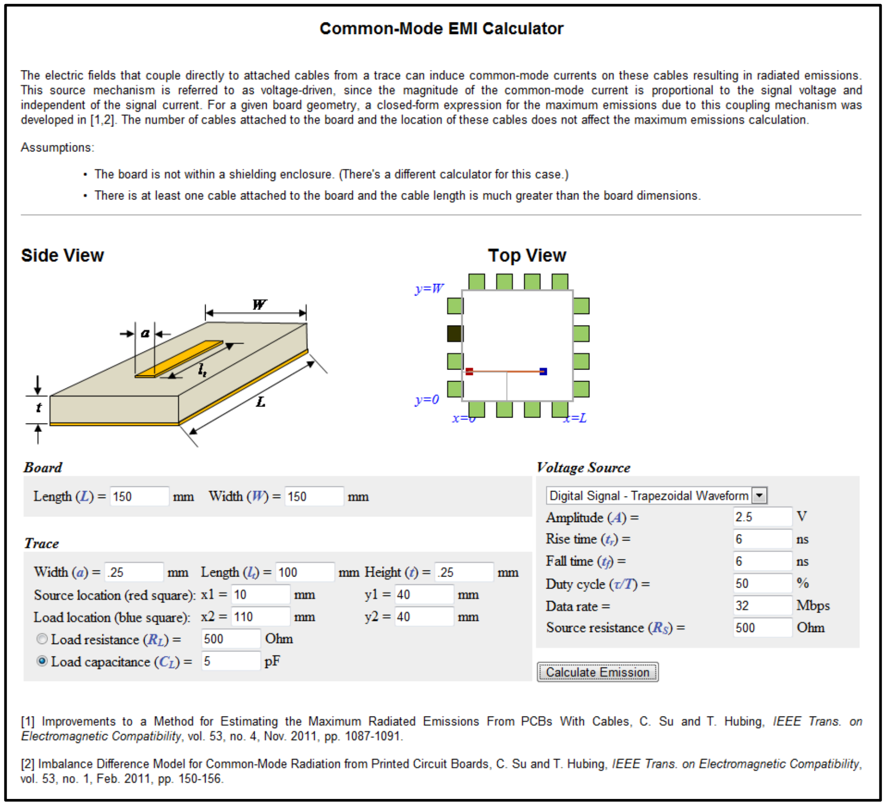
[2] Imbalance Difference Model for Common-Mode Radiation from Printed Circuit Boards, C. Su and T. Hubing, *IEEE Trans. on Electromagnetic Compatibility*, vol. 53, no. 1, Feb. 2011, pp. 150-156.



MREMC Algorithms (Nets)



Trace Drives an Attached Cable and/or Heatsink



Common-Mode EMI Calculator

The electric fields that couple directly to attached cables from a trace can induce common-mode currents on these cables resulting in radiated emissions. This source mechanism is referred to as voltage-driven, since the magnitude of the common-mode current is proportional to the signal voltage and independent of the signal current. For a given board geometry, a closed-form expression for the maximum emissions due to this coupling mechanism was developed in [1,2]. The number of cables attached to the board and the location of these cables does not affect the maximum emissions calculation.

Assumptions:

- The board is not within a shielding enclosure. (There's a different calculator for this case.)
- There is at least one cable attached to the board and the cable length is much greater than the board dimensions.

Side View **Top View**

Board

Length (L) = 150 mm Width (W) = 150 mm

Trace

Width (a) = .25 mm Length (l_t) = 100 mm Height (t) = .25 mm

Source location (red square): x1 = 10 mm y1 = 40 mm

Load location (blue square): x2 = 110 mm y2 = 40 mm

Load resistance (R_L) = 500 Ohm

Load capacitance (C_L) = 5 pF

Voltage Source

Digital Signal - Trapezoidal Waveform

Amplitude (A) = 2.5 V

Rise time (t_r) = 6 ns

Fall time (t_f) = 6 ns

Duty cycle (τ/T) = 50 %

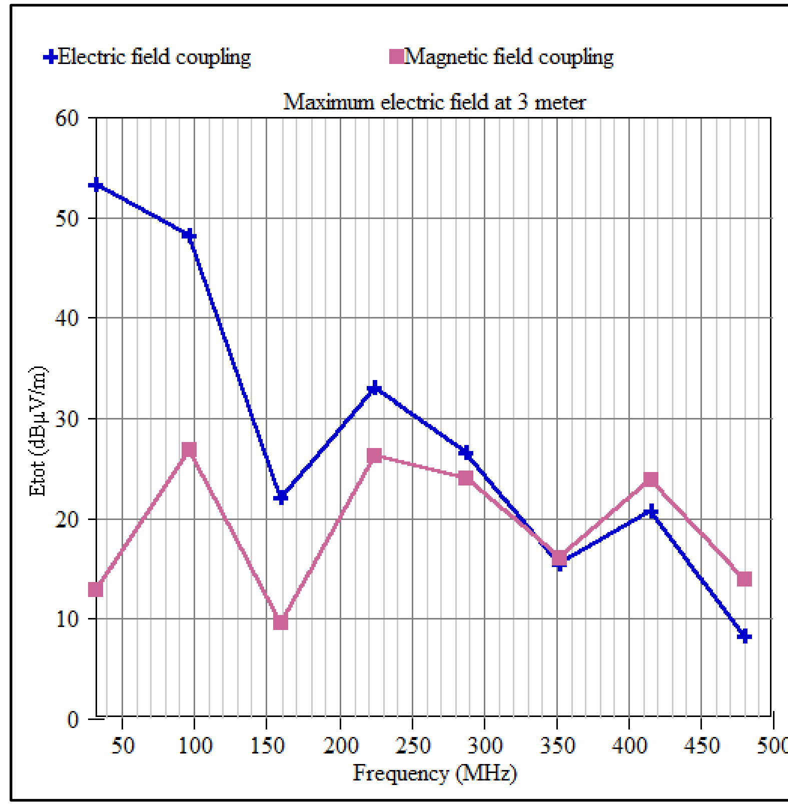
Data rate = 32 Mbps

Source resistance (R_S) = 500 Ohm

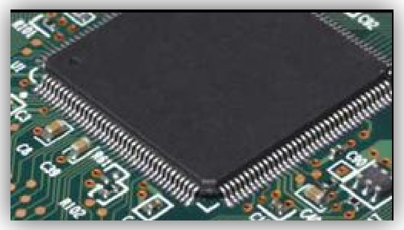
Calculate Emission

[1] Improvements to a Method for Estimating the Maximum Radiated Emissions From PCBs With Cables, C. Su and T. Hubing, *IEEE Trans. on Electromagnetic Compatibility*, vol. 53, no. 4, Nov. 2011, pp. 1087-1091.

[2] Imbalance Difference Model for Common-Mode Radiation from Printed Circuit Boards, C. Su and T. Hubing, *IEEE Trans. on Electromagnetic Compatibility*, vol. 53, no. 1, Feb. 2011, pp. 150-156.

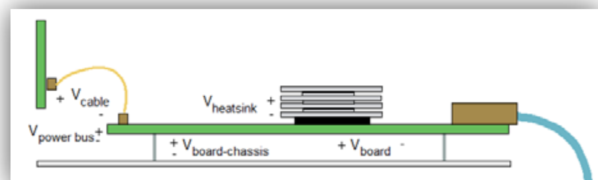


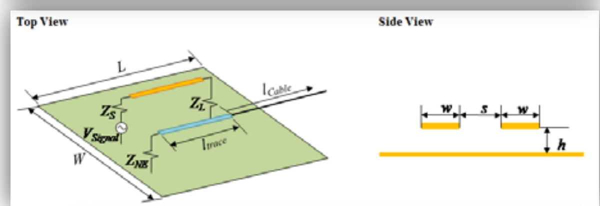
MREMC Algorithms (Components)



Direct Radiation from Component

Negligible



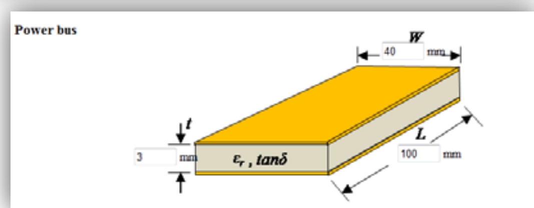


Component Drives an Attached Cable and/or Heatsink

Measure or model the equivalent dipole source for the component and use the trace algorithm

Component Couples to another Trace that Drives an Attached Cable

Measure or model the equivalent dipole source for the component and use the trace algorithm

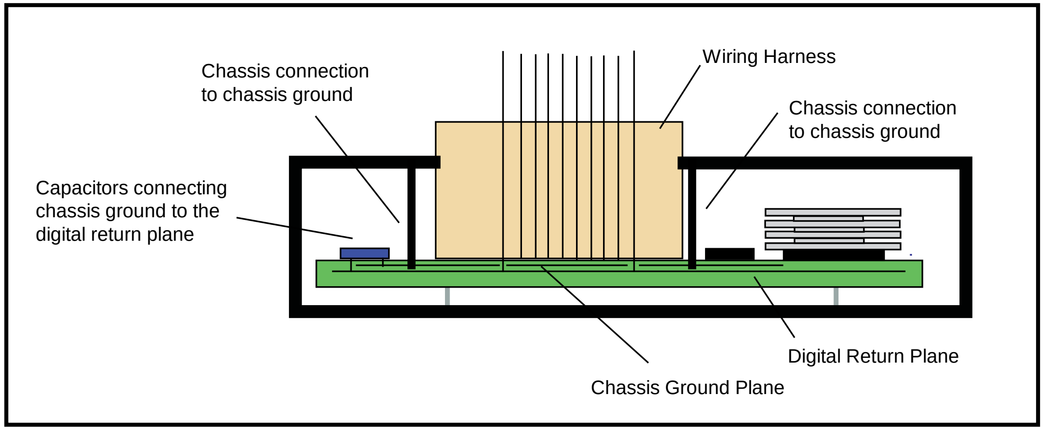


Component Drives the Power Bus

Need to know: board dimensions, CPD and load Cs, component datasheet information

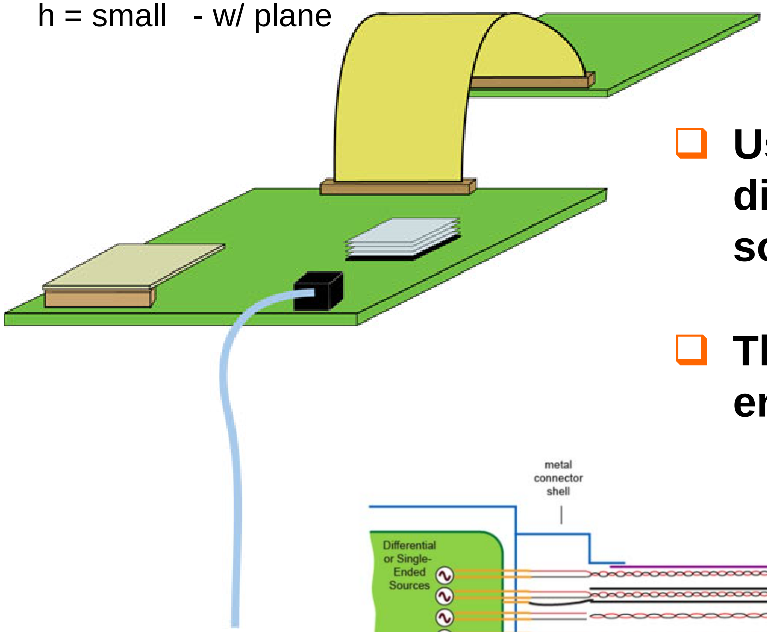
MREMC Algorithms (Shielded Products)

- Board analysis should be done as if there were no shield
- E-field coupling problems can be mitigated with E-field shielding
- Common-mode currents on cables can be mitigated enclosure to cable filtering

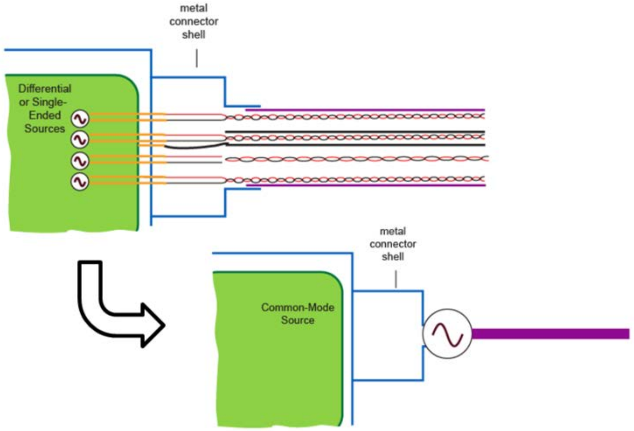


MREMC Algorithms (Differential Signals)

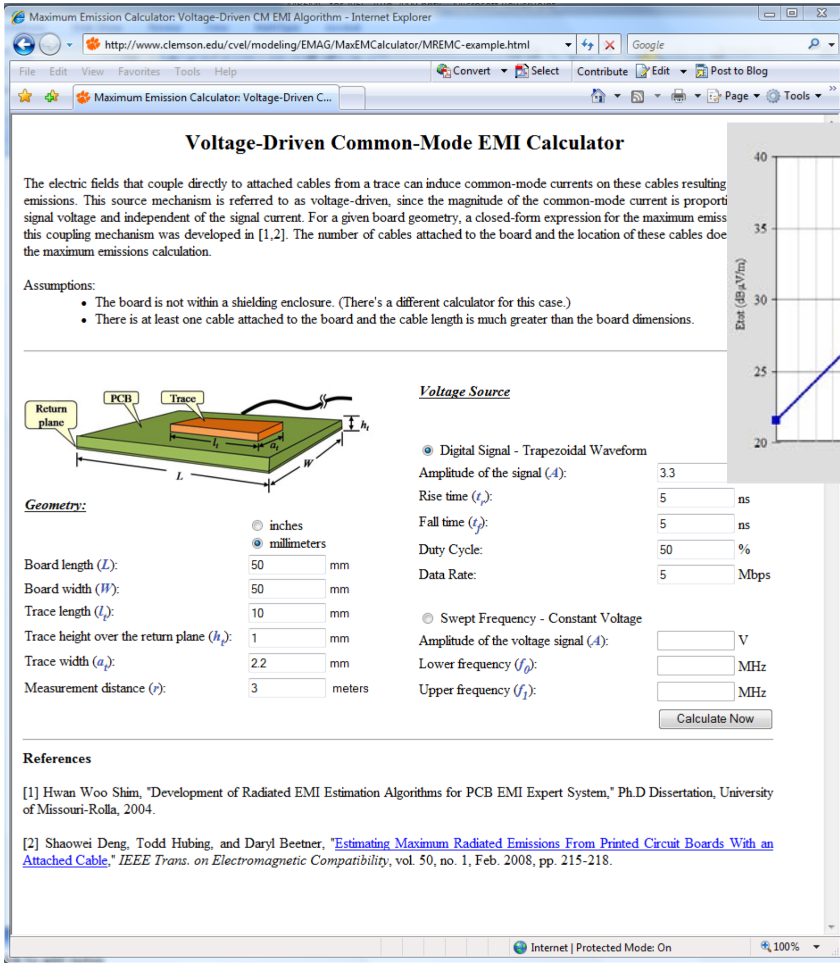
h = 0.5 - no plane
h = small - w/ plane

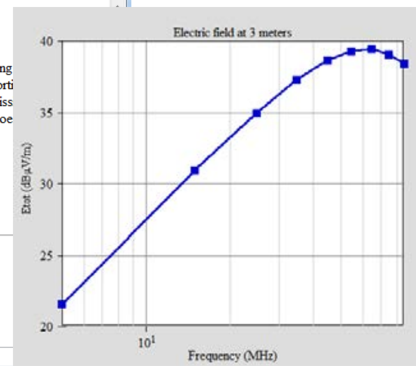


- Use Imbalance Difference Model to convert all differential signals to equivalent common-mode sources
- Then apply the same algorithms used for single-ended signals

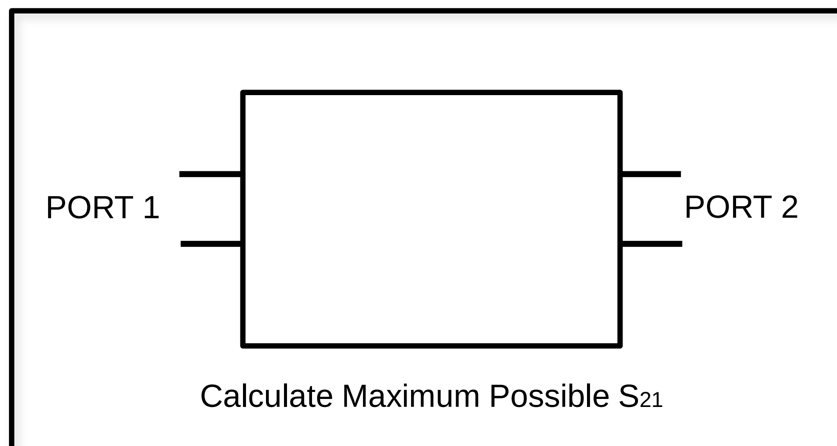


Susceptibility Calculations



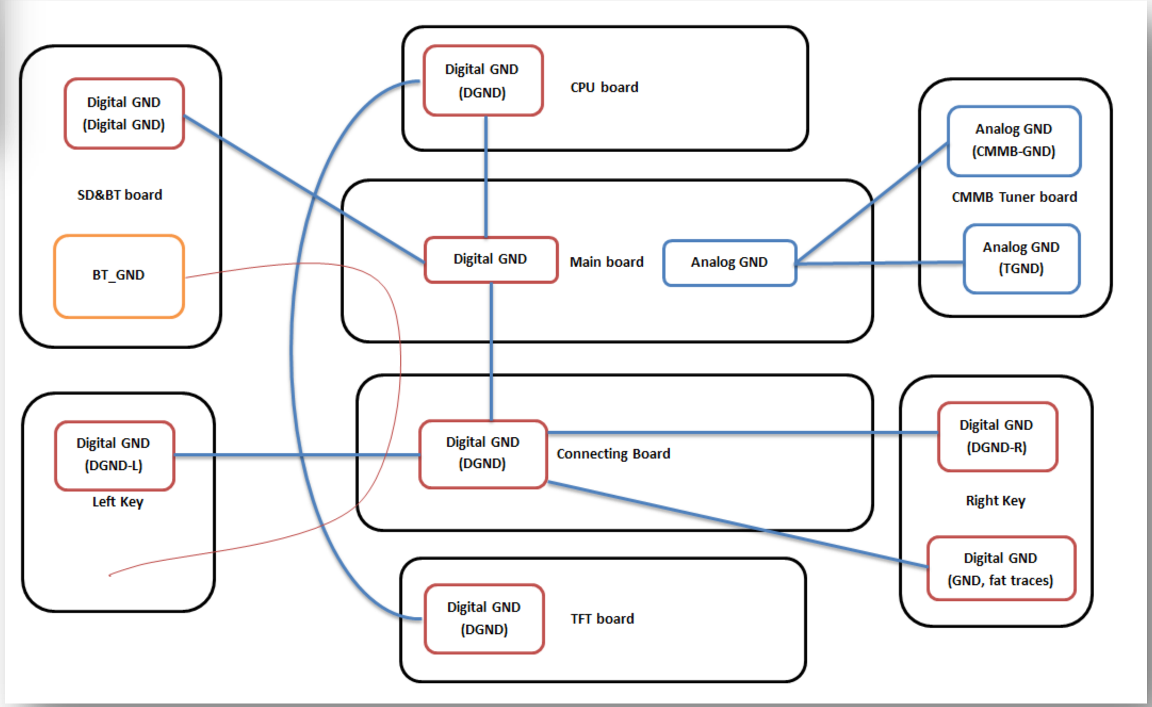


Maximum Radiated Emissions Calculator (MREMC)



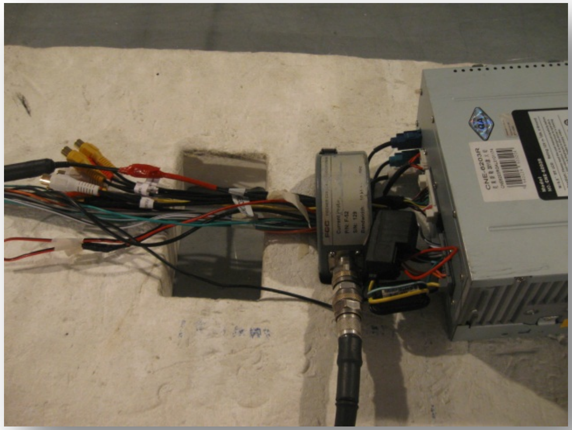
Application to Infotainment System

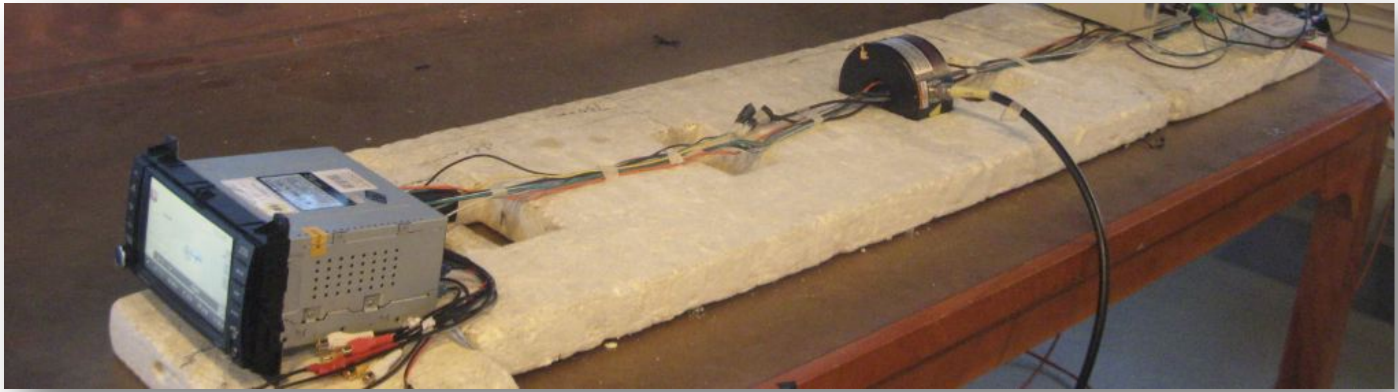
- 5 Circuit Boards, mixed-signal RF, audio, video
- Internal ribbon cable connections
- Unshielded external connections



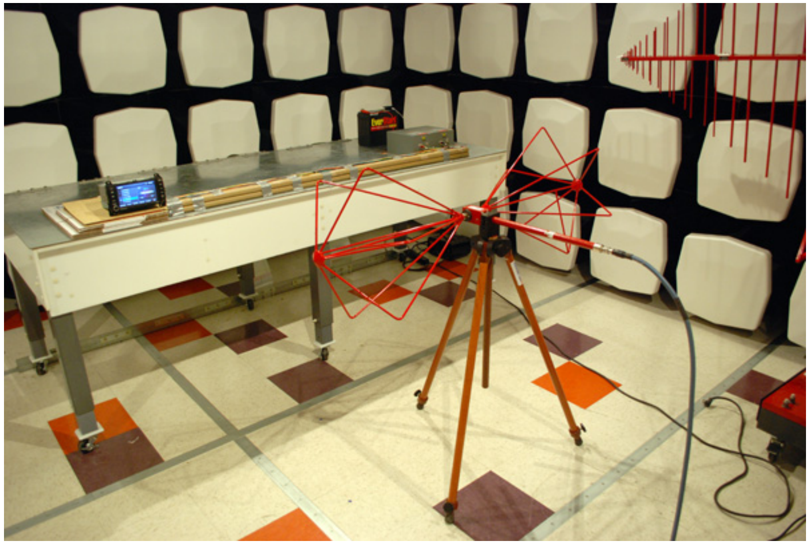
- AM/FM Radio
- 3 Camera Interfaces
- GPS
- DVD Player
- USB
- Fold-out Display

EMC Testing





Identify Antennas

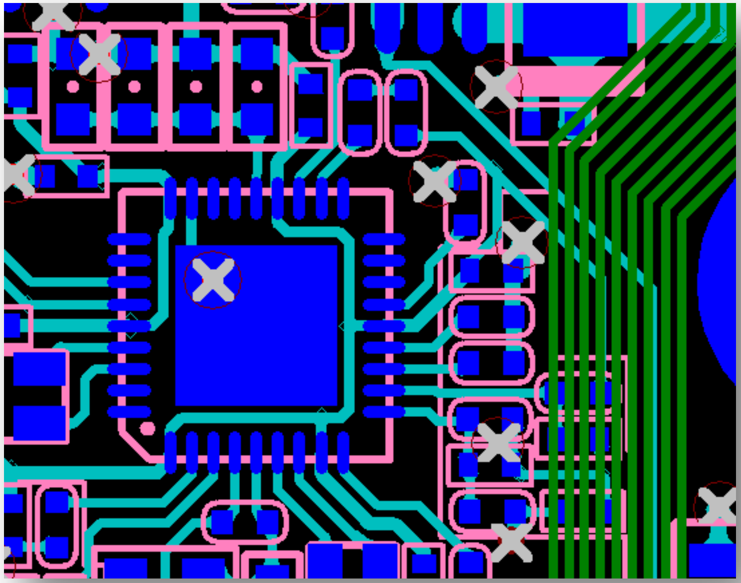


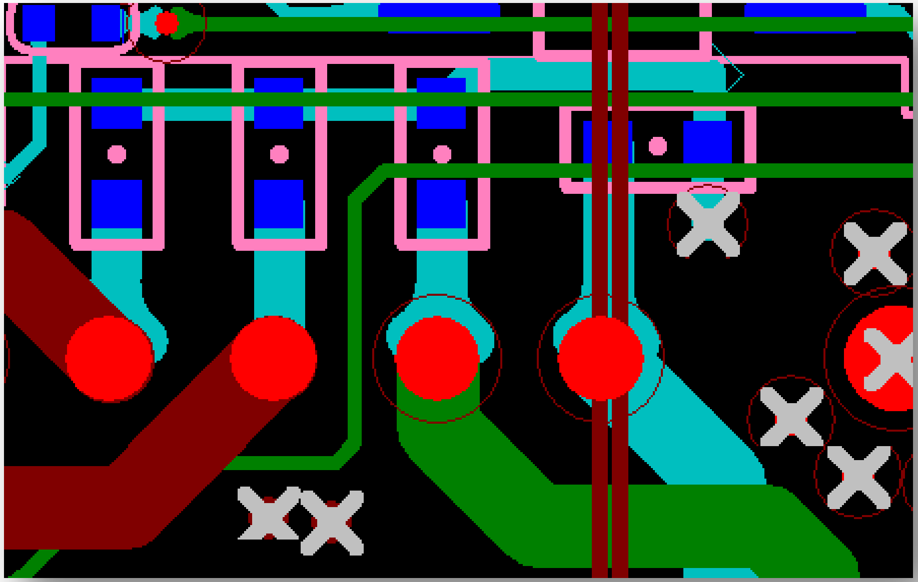
Design Guidelines

Many design "rules" were violated in the final design. Attempting to comply with a complete list of design rules would have made the product unnecessarily expensive.

Nevertheless, some rules make too much sense to ignore. (Even if they are not explicitly required.)

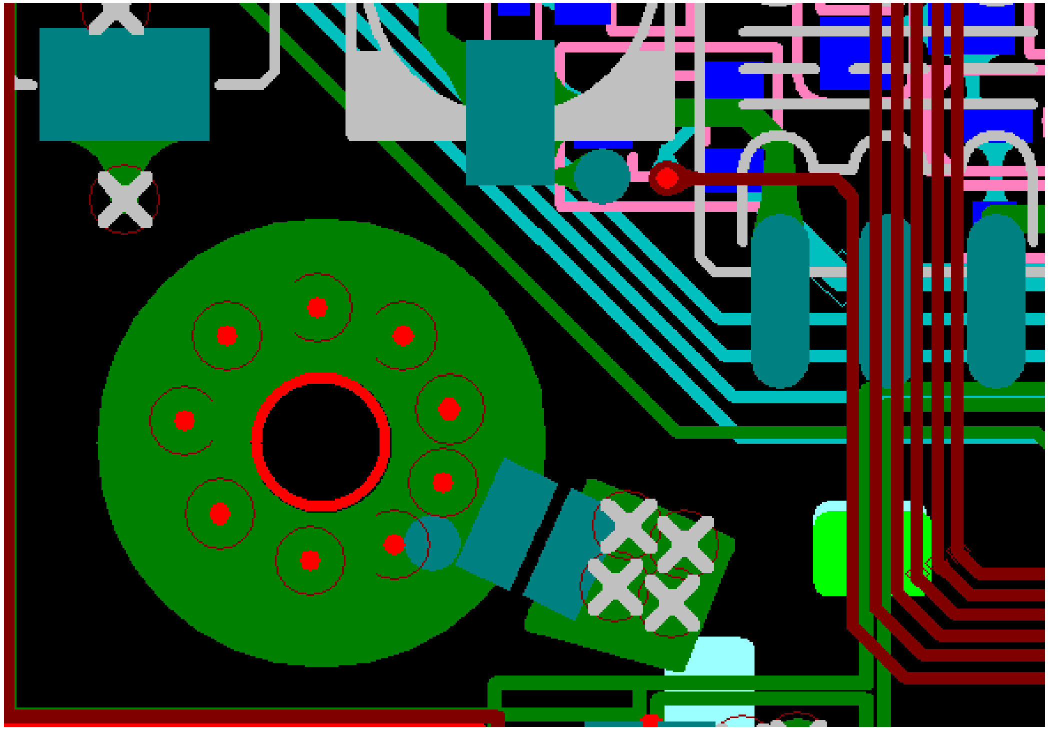
e.g.
No ground traces.
No shared ground vias.





Design Flexibility

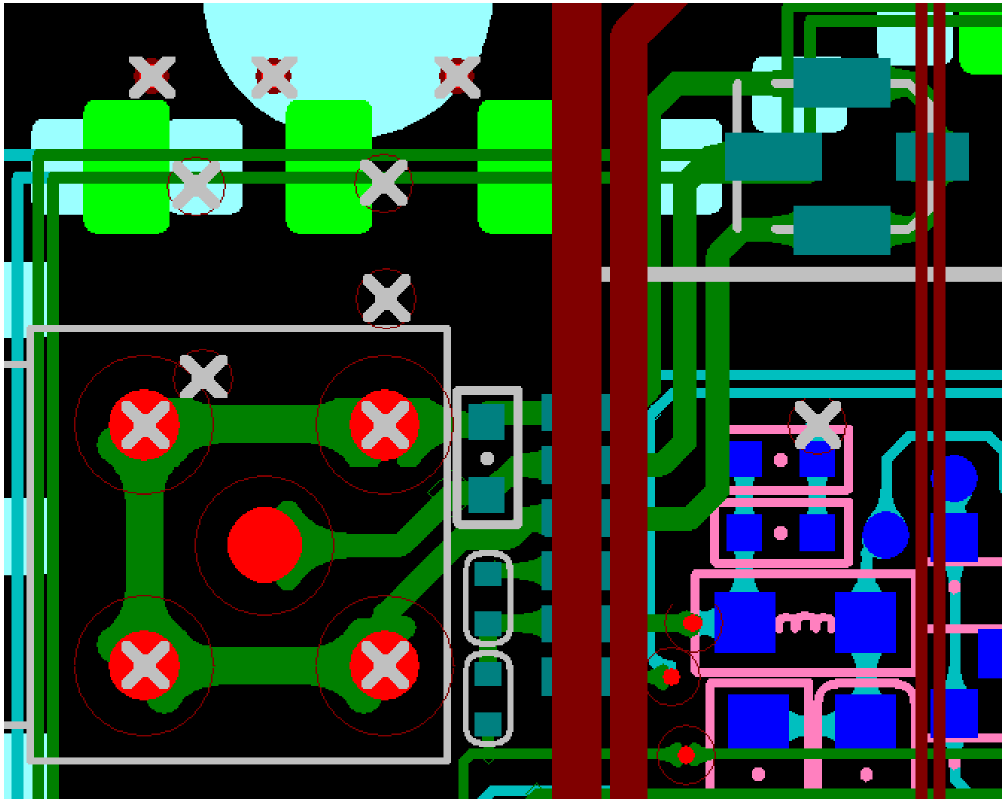
It's a good idea to leave options open to deal with unexpected issues.



e.g. grounding option

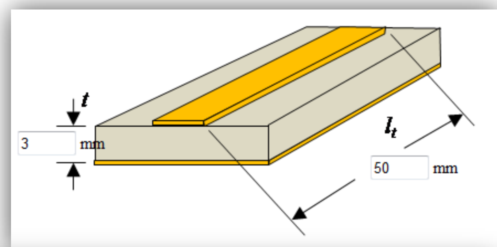
Design Standards

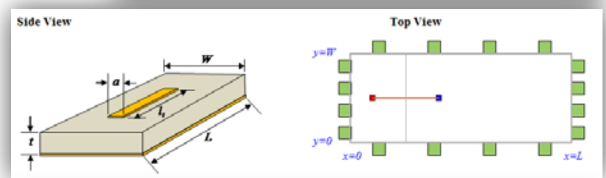
Many circuit geometries were based on known success with prior products.

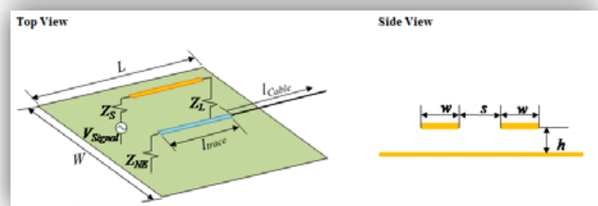


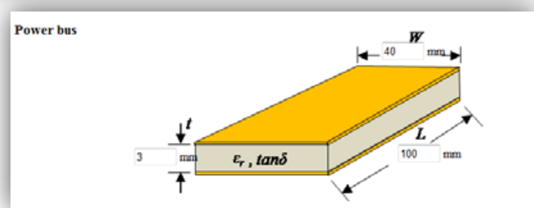
e.g. GPS antenna interface

For This Product Design (Nets)









Direct Radiation from Trace

No calculations made. Provided HF current return for all nets not eliminated after Step 1 (critical nets).

Trace Drives an Attached Cable and/or Heatsink

Optimized each critical net, but relied on filtering to chassis to guarantee compliance.

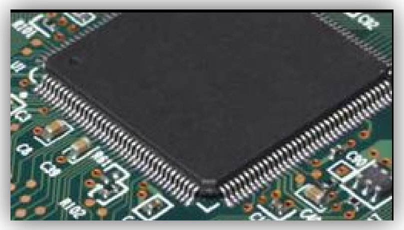
Trace Couples to another Trace that Drives an Attached Cable

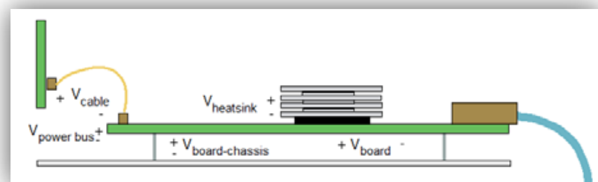
No calculations made. Visually highlighted all I/O and kept several trace heights away from critical nets.

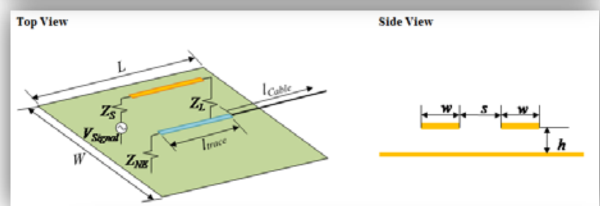
Trace Drives the Power Bus

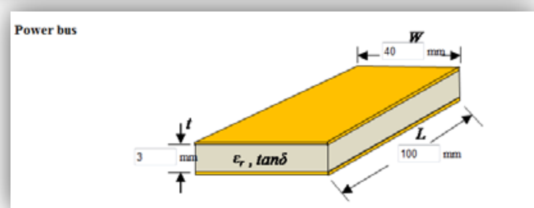
No calculations made. Focused on providing excellent HF decoupling.

For This Product Design (Components)









Direct Radiation from Component

No calculations made. Negligible.

Component Drives an Attached Cable and/or Heatsink

No calculations made. Judged to be a non-issue.

Component Couples to another Trace that Drives an Attached Cable

No calculations made. Visually highlighted all I/O and kept critical components away.

Component Drives the Power Bus

No calculations made. Focused on providing excellent HF decoupling.

Current Project Status

- Documenting MREMC algorithms
- Increasing awareness
- Looking for software partner
- Formulating radiated susceptibility algorithms

Performance-Based EMC Design of Electronic Systems

Designing Automotive Components for Guaranteed Compliance with Electromagnetic Compatibility Requirements

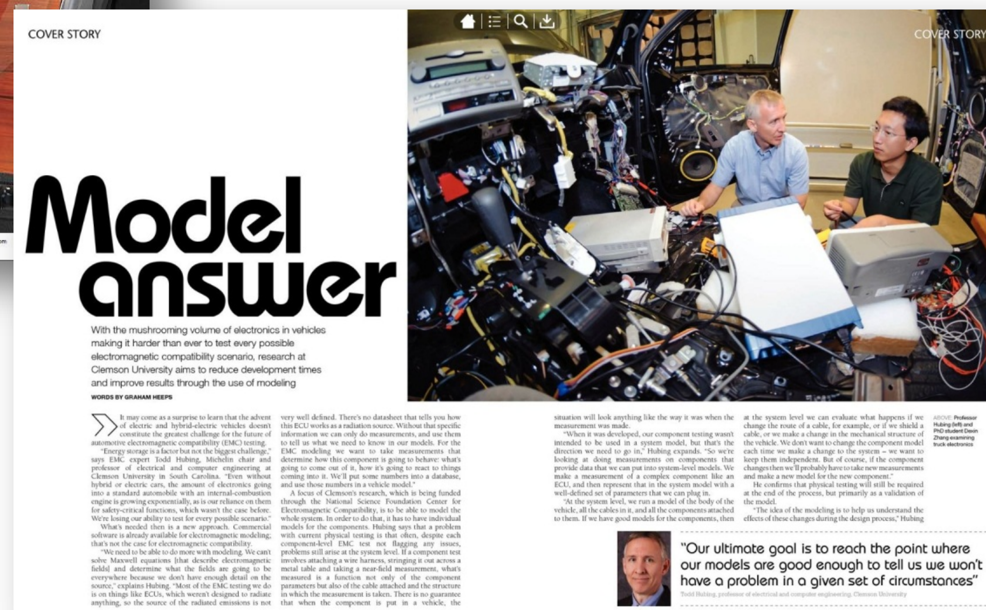
BY TODD HUBING

Automobiles typically have dozens of electronic systems operating interactively in a relatively compact space. These systems must operate reliably in a wide range of environments over extended periods of time. As a growing number of these systems play an ever expanding role in protecting the safety of a vehicle's occupants, there is an increasing need to ensure that the integrity of these systems will not be compromised by electromagnetic interference.

The traditional design, build and test approach to automotive EMC compliance will not be sufficient to ensure the safety or reliability of tomorrow's automobiles. A *Design for Guaranteed Compliance* approach promises to ensure that automotive components will meet all EMC requirements the first time they are tested, and that compatibility will not depend on the specific vehicle or system in which the components are installed. More work needs to be done before this concept reaches its full potential, but electronic system designers can already derive significant benefit by applying this approach to products currently under development.

1 In Compliance Month 2012 www.incompliancemag.com

In Compliance Magazine, May 2013.



COVER STORY

Model answer

With the mushrooming volume of electronics in vehicles making it harder than ever to test every possible electromagnetic compatibility scenario, research at Clemson University aims to reduce development times and improve results through the use of modeling

WORDS BY GRAHAM HEEPS

It may come as a surprise to learn that the advent of electric and hybrid-electric vehicles doesn't constitute the greatest challenge for the future of automotive electromagnetic compatibility (EMC) testing.

"Energy storage is a factor but not the biggest challenge," says EMC expert Todd Hubing, Michelin chair and ...

"Our ultimate goal is to reach the point where our models are good enough to tell us we won't have a problem in a given set of circumstances"

Automotive Testing Technology International, Nov. 2012.

Expected Outcomes

- Software tools will make this technique easier to implement and accessible to non-expert design engineers
- Will increase consumer demand for EMC-specific component information
- Will not replace EMC engineers, but will allow more sophisticated designs
- Will help engineers to use numerical EM modeling tools more effectively